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REGENERATION OF HEATH AND HEATH WOODLAND IN THE NORTH-EASTERN OTWAY RANGES FOLLOWING THE WILDFIRE OF FEBRUARY 1983

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Abstract: Vegetation in the Anglesea district includes floristically-diverse and species-rich heath, tall shrubland, scrub and woodland communities. Plant species richnesses range from 53-134 per community. Variations in floristics and structure reflect differences in proximity to the sea, topography, soil structure and fertility, fire history and the presence of the pathogen *Phytophthora cinnamomi*.

Following the wildfire of February 1983, ninety percent of all species present before the fire reappeared within the first year. All other species returned by year two. Thirty seven percent of all species regenerated vegetatively, 30% vegetatively and from seed, and 33% from seed only. Rate of recovery of cover of the shrub stratum in heaths and heath woodlands was faster than the rate of recovery of height (74% cf. 46% at 3 years). In contrast, the rate of recovery of canopy height in heath woodlands was faster than the rate of recovery of canopy cover (88% cf. 66% at 3 years).

Fifty two percent of species flowered in the first year after fire, and 98% had flowered by the end of the third year. Most of the species which flowered during the first year were herbaceous, and included members of the Liliaceae, Orchidaceae, Droseraceae, Asteraceae and Gramineae. This early "herbaceous phase" declined in cover and density of flowering during the second and third years as shrub cover increased. Grazing by native and introduced mammals reduced the frequency and density of herbaceous species in the early years after fire. Though most shrubs commenced flowering within two years of fire, few produced seed, suggesting that early post-fire flowering may not necessarily result in early seeding. Burning of the heaths and woodlands before these species reach reproductive maturity could cause long term changes in structure and diversity by eliminating obligate seed regenerators.

The north-eastern Otway Ranges, Victoria (Fig. 1) is a species-rich area of south-eastern Australia. Over 690 species of indigenous vascular plants (26% of the total Victorian flora), 25 species of native mammals and 150 species of native birds occur in the area (White 1984, Reilly 1985, Wilson & Maloney 1985). The region contains extensive dry sclerophyll forests and heath woodlands prone to fire. Prior to 1983 there had been no published study on the fire ecology of the flora and fauna of this area. Following the wildfires of Ash Wednesday (17 February 1983), in which 37,000 ha of vegetation near Anglesea and Aireys Inlet were burnt, a ten year study of post-fire recovery of vegetation and fauna was initiated.

The aims of this project were:
1. to describe vegetation regeneration following wildfire in six of the major plant communities in the district (coastal heath, heath woodland, ironbark forest, sand-dune scrub, swamp thicket and fern gully);
2. to examine post-fire recolonization of these plant communities by small mammals, birds and insects; and,
3. to provide information for use in planning of conservation management.

This paper presents data on regeneration of coastal heath and heath woodland communities in the first three years after fire, and describes their floristics and structure. Regeneration strategies and post-fire flowering response of species in these communities are also described. Mammal, bird and insect data have been reported separately (Reilly 1985, Wilson & Moloney 1985, Andersen 1987).

SITE DESCRIPTIONS

Three sites (A, B and C) containing heath and heath woodland communities (Fig. 1, Table 1) were selected in undulating terrain on soils derived from Tertiary sediments known as the Eastern View and Demons Bluff Formations (Pitt 1981). Site A was on a coastal cliff top, and the other two sites were 2 to 4 km inland. All sites supported natural vegetation.

Each site contained several plant communities (subsites) ranging from closed heath to woodland. The structural terminology used follows Specht (1970). Overstorey eucalypts were of mixed age, density and species, and all subsites had heathy understoreys (Tables 1 & 2). Except for subsite B1, which may have been affected by strip mining of gravel, all subsites were undisturbed.

The fire history of each site differed (Table 1). The high-intensity 1983 wildfire destroyed all surface vegetation and crown-fired or 100% crown-scorched the eucalypt overstorey at all subsites (Table 1). This fire occurred following a drought year (1982) in which the total rainfall at Anglesea was 452 mm, 68% of the annual mean (657 mm). Rains of over 80 mm fell one, three, seven and eight months after the fire. Total rainfalls for 1983, 1984 and 1985 were 683, 685 and 717 mm respectively.

Because of the extent of the fires, no comparable unburnt subsites were available for study.

TABLE I
SITE DESCRIPTIONS

Site	Location Height above SL Topography Geological Origin	Fire History before Ash Wed.	Fire Intensity Ash Wed. (1983)	Floristic Alliance	Subsite	Aspect	Soil Profile (A Horizon) 3 Years After Fire	Vegetation Formation	Dominant Species	Approx.* Prefire Height (m)	Height 3 Years after Fire (m)	No. of Quadrats Yr.1	No. of Quadrats Yr.3	Area Sampled (ha)
A (Point Addis Road)	Coastal, 100 m above SL and 50-100 m from cliff edge. Topography flat to gently sloping. Soils derived from Demons Bluff Formation.	All burnt by wildfire 1958	All crown fired	I	A1	SE/E 1.5°	30 cm ** sandy loam 10 YR 3/3 10 YR 5/8	closed heath	Leptospermum myrsinoides Banksia marginata Casuarina pusilla	0.4	0.2	11	13	1.0
					A2	S/SE 3°	30 cm ** sandy loam 10 YR 4/4 10 YR 5/6	open scrub	Eucalyptus obliqua	4.4	3.7	1	6	0.5
					A3	N/NW 7°	12.5 cm ** sandy clay loam 7.5 YR 6/6	tall shrubland	Eucalyptus obliqua	2.5	2.25	6	7	0.5
B (Harrison Track)	4 km inland, 50 m above SL in watershed of Anglesea River. Topography undulating. Soils derived from Eastern View Formation.	All control burnt 1973	All 100% crown scorch	I	B1	N 10°	80 cm loamy coarse sand 10 YR 10 YR	woodland	Eucalyptus obliqua	11.7	10.7	3	3	0.25
				II	B2	S 9°	53 cm loamy coarse sand 10 YR 4/2 10 YR 6/4	woodland	"	11.8	10.3	1	5	0.5
					B3	S 17°	40 cm# loamy coarse sand 10 YR 4/2 10 YR 3/2	woodland/ closed scrub (ecotone)	"	10.4	8.7	2	6	0.25

TABLE I (continued)

Site	Location Height above SL Topography Geological Origin	Fire History before Ash Wed.	Fire Intensity Ash Wed. (1983)	Floristic Alliance	Subsite	Aspect	Soil Profile (A Horizon) 3 Years After Fire	Vegetation Formation	Dominant Species	Approx.* Prefire Height (m)	Height 3 Years after Fire (m)	No. of Quadrats Yr.1	No. of Quadrats Yr.3	Area Sampled (ha)
C (Coalmine Road)	2 km inland, 50-75 m above SL in watershed of Salt Creek near open cut coal mine. Topography undulating. Soils derived from both Eastern View & Demons Bluff Formation.	All burnt by wildfire 1969	All crown fired	II	C1	N/NW 5°	23 cm ** sandy loam 10 YR 7/4	woodland/ tall shrubland	Eucalyptus baxteri / Eucalyptus willisii	6.2	4.8	5	5	1.0
					C2	N/NW 7°	43 cm sandy loam 10 YR 5/2 10 YR 4/6	tall shrubland/ woodland	Eucalyptus willisii / Eucalyptus baxteri	4.6	5.1	3	5	0.25
					C3	W 2°	43 cm # sandy loam 10 YR 3/2 10 YR 4/6	open heath	Leptospermum juniperinum / Gahnia radula	2.5	1.1	5	5	0.5
			100% crown scorch		C4	N/NE 7°	53 cm sandy loam 10 YR 10 YR	woodland/ tall shrubland	Eucalyptus obliqua / Eucalyptus willisii	7.5	7.5	2	3	0.5

* tallest stratum; ** iron nodules present; # coffee rock present

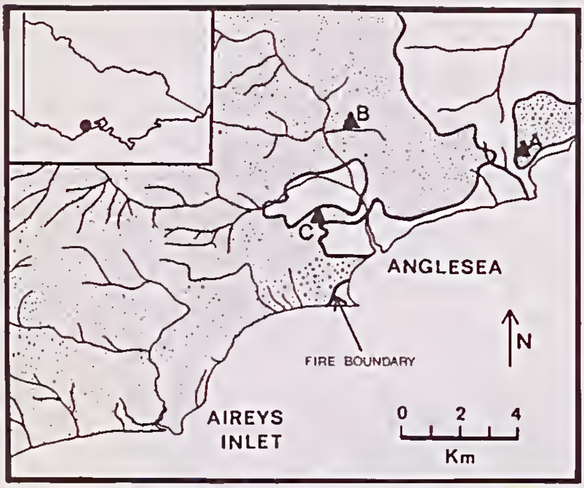


Fig. 1—Locality map showing location of the eastern Otway Ranges, Victoria, and sites A, B and C near Anglesea. Stippling indicates the area burnt on 16 February 1983. The fire advanced from the south west.

METHODS

Soils

Soils were sampled at all subsites at 2 months, 1 and 2 years after fire. Two month and one year samples were single topsoil cores (10×10 cm deep) taken adjacent to quadrats. Two year samples consisted of composite samples of 40 topsoil cores (2×10 cm deep) taken randomly throughout each subsite using a Soilcrete soil sampler (Selby-Anax, Sydney).

Profiles

Soil profiles were examined at each subsite by digging pits down to the upper B horizon. For each pit, colour and texture variations of the A and B horizons and the depth of the A horizon were recorded. Colour was determined using Munsell soil colour charts (Kollmorgen Corporation, Maryland, 1975).

Chemical analysis

Samples of the A horizon collected 1 and 2 years post-fire (at all subsites except B1 and C4) were tested for pH and analysed for available P, total Kjeldahl N, organic C, and exchangeable Na, K, Ca and Mg by the State Chemistry Laboratory, Victoria. Procedures used are described in their Methods Manual (Anon 1986) under the following codes: soils 009 (pH), soils 010 (Olsen phosphorus), soils 006 (exchangeable cations; Tucker), soils 007 (total Kjeldahl nitrogen), soils 014 (organic carbon; Walkley & Black).

Moisture

Field observations were made of soil water-logging at all sites and plant species found in damp areas were noted.

Soil pathogens

Samples of surface soil 10×10 cm, taken near dying plants of *Isopogon ceratophyllus* and *Xanthorrhoea australis* three years after the fire were tested for the presence of infectious propagules of *Phytophthora cinnamomi* by Dr. G. C. Marks (Von Mueller Institute, Victoria) using a cotyledon baiting technique (Marks & Kassaby 1974). Sites where *Phytophthora* infection may have been present pre-fire were identified by the presence of burnt-out bases of stems of *Xanthorrhoea australis.*

Vegetation

Prefire data

Detailed species lists were prepared for each site prior to the 1983 fire. However, no quantitative data on pre-fire floristics or vegetation structure were available.

Data collection

Fifty-eight 1×2 m permanent quadrats, placed randomly on 0.25—1 ha subsites (Table 1) one month after the fire, were used to record floristic composition and structural changes in the understorey in autumn and spring for three years after fire (2, 8, 14, 20, 26 and 32 months). Number, maximum height and cover values were recorded for all species of vascular plants, mosses, liverworts and lichens. Cover values of bare ground and litter were also recorded. Cover values were scored on the Braun-Blanquet scale (Mueller-Dombois & Ellenberg 1974). Records were made of regeneration strategies and flowering times of all species 2-32 months after fire. Field observations were used to supplement quadrat data on floristics, flowering and regeneration strategies. Nomenclature of plants follows Forbes *et al* (1984) except for the recently described *Grevillea infecunda* D. J. McGillvray (1986) and *Hakea repullulans* H. M. Lee (1985). Nomenclature of Orchidaceae follows Clements (1985) and Weber and Bates (1986); mosses—Scott and Stone (1976); liverworts—Scott (1985); and, lichens—Filson and Rogers (1976).

The density and regeneration strategies of the dominant eucalypts were recorded. Rectangular extended plots (11×12 m) were used to map positions of trees adjacent to the small quadrats, and to monitor canopy recovery with time. Pre-fire heights were estimated from charred canopy remains.

Regrowth of established trees (stems > 10 cm girth) was measured by changes in trunk girth, total regrowth height, mean canopy width, and maximum length of basal, trunk and crown epicormics. Height data presented were derived from measurements of 10-15 trees of the tallest stratum per subsite. Girths of trunks were measured at the base in coastal shrubland, and at 1.45 m in scrub, tall shrubland and woodland.

Data analysis

Floristic data were analysed by computer classification and ordination techniques using four programs of the CSIRO "Taxon" range, MACINF, GCOM, PCOA and BACRIV (Williams 1976, Ross 1982). The survey data matrix (95 quadrats×171 species) was coded in binary format (presence/absence only) and the programs used to evaluate variability within and between communities of the three sites at one and three years after fire.

Structural data were analysed graphically. Vegetation profiles were prepared for all subsites following the fire, and at yearly intervals thereafter.

RESULTS

Soils

Profiles

All soils were duplex, with A horizons of variable depth (0.125–0.8 m) and texture (loamy sand, sand or gravel–Table 1). Iron nodules were present in soils derived from the Demons's Bluff Formation (Subsites A1, A2, A3, C1). Colour of the A horizon was similar for 9 of the 10 subsites–falling in the Munsell 10 YR range. The one exception had an eroded profile (subsite A3, 7.5 YR–Table 1). The upper horizon was composed either of sandy clay, clayey sand, sand, gravel or coffee rock. Both profiles containing coffee rock were from subsites with perched water tables for part of the year.

Chemical analysis

Soils at the subsites ranged in pH from 4.3–5.8, and all were low in nutrient cations, N, P and organic matter (Table 5). No significant difference in fertility was seen between soils of heath or heath woodland. The level of Na, Ca, Mg and K was higher in coastal soils (site A), probably due to its geological history and salt spray deposition from on-shore winds (Parsons & Gill 1968, Parsons 1979).

Analyses of topsoil sampled one and two years after fire showed no significant change in nutrient levels between these times (Table 5, $P>0.05$), and suggests that any "ash bed" effect had disappeared by the first year. Unfortunately topsoil samples collected two months after the fire were mislaid so no information is available on nutrient levels immediately after fire.

Moisture

All soils were waterlogged during winter (June-August) and appeared droughted during summer (December-February). *Gahnia radula* was present in damp areas at all sites.

Phytophthora cinnamomi

Phytophthora cinnamomi was isolated from soil at most sites three years after the fire. Symptoms of disease (dead or dying plants of *Xanthorrhoea australis, Isopogon ceratophyllus* and *Banksia marginata*) were quite common at 6 subsites (A2, B1, B2, B3, C2 and C3) all situated on slopes, near roads, or along drainage lines. A few burnt-out bases of *Xanthorrhoea* were present at all these subsites, suggesting that *Phytophthora* was present and had killed some *Xanthorrhoea* well before the fire occurred.

Upslope from subsites B2 and B3, the understorey was composed of sedges (*Lepidosperma semiteres, Gahnia radula*) and burnt-out bases of *Xanthorrhoea*. No sclerophyllous heath species was found. Lower down the slope (subsites B2, B3) signs of *Phytophthora* infection were appearing in the heathy understorey–including chlorosis, dieback and death of *X. australis, I. ceratophyllus, Monotoca scoparia, Epacris impressa* and *B. marginata*. These signs were most marked at subsite B3, a subsite with a high water table, located below a fire access track. Here about 12% of *Xanthorrhoea* plants which resprouted following the fire died by the third year.

Vegetation

Floristics

A total of 252 species were recorded prior to the fire (Table 2). All reappeared in the first three years after fire. One additional species, *Opercularia scabrida*, not previously recorded in the district, appeared two years after fire.

Seven introduced species were present at low density in communities adjacent to grazing lands (*Aira caryophylla, Vulpia myuros*), or along drainage lines below roads (*Holcus lanatus, Hypochoeris radicata, Cirsium vulgare*).

A total of 6 tree species, 67 shrubs, 141 herbs (including 40 orchid species), 22 species of graminoids, 7 ferns and 12 non-vascular plants were present (Table 2). (In this paper the term herb will be used to mean herbaceous species and will include members of 25 families of vascular plants including Asteraceae, Droseraceae, Gramineae, Iridaceae, Liliaceae and Orchidaceae. Similarly, graminoids will be used to mean sedges and rushes–families Cyperaceae, Juncaceae and Restionaceae.) The proportions of trees, shrubs, herbs, graminoids and other groups differed little between plant communities. Two heath communities (subsites A1 and C3) and eight heath woodland communities (subsites, A2, A3, B1, B2, B3, C1, C2 and C4) were identified (Table 2).

The most widespread tree, *Eucalyptus obliqua*, occurred in varying proportions (3-940 stems/ha) in all subcommunities, and ranged in habit from 11.8 m single-trunked trees in sheltered areas (Table 1, Fig. 4) to low, sprawling 2.5 m multi-stemmed shrubs on exposed cliff tops (Table 1, Fig. 3). Density of seedlings of *E. obliqua* three years after fire ranged from 5-15/hectare in heaths to 1300-5000/hectare in heath woodland communities.

Plant communities were floristically diverse. Species numbers ranged from 69-107 for heath subcommunities (Fig. 2), and from 53-134 for heath woodland subcommunities. Fifty to eighty percent of species in each subcommunity were sampled in the 1×2 m permanent quadrats at year 3, giving a species richness in quadrats of 36-66 species. Fifteen species were found in all 10 subcommunities, including *Banksia marginata, Epacris impressa, Leptospermum myrsinoides, Gahnia radula* and several species of herbs. Floristics of these subcommunities are presented as presence-absence data in Table 2. Data on species density, frequency and cover are available from the authors.

Computer analysis (using classification techniques) divided the plant communities into two distinct floristic alliances (Fig. 2) on the basis of common understorey species. Further subdivision revealed the presence of 10 distinct subcommunities (all with heathy understories) and identified floristic differences between them (Fig. 2, Table 2). Ordination techniques (data not presented here) confirmed these results. Computer analysis also showed that the species composition of each subcommunity

TABLE 2

FLORISTIC COMPARISONS BETWEEN SUBSITES 1 & 3 YEARS AFTER FIRE

KEY: 1 = present in quadrats year 1; 3 = present in quadrats year 3; (1) = present at site year 1; (3) = present at site year 3; *11 × 12 m quadrats;** 1 × 2 m quadrats.

SITE	A						B						C							
SUBSITE	A1		A2		A3		B1		B2		B3		C1		C2		C3		C4	
VEGETATION FORMATION	Closed Heath		Open Scrub		Tall Shrubland		Woodland		Woodland		Woodland/ Closed Scrub		Tall Shrubland/ Woodland		Tall Shrubland/ Woodland		Open Heath		Woodland/ Tall Shrubland	
TREES *																				
MYRTACEAE																				
Eucalyptus aromaphloia							(1)	(3)												
" baxteri			1	3			(1)						1	3	(1)	(3)			(1)	(3)
" obliqua	(1)	(3)	1	3	1	3	1	3		3	1	3	(1)	(3)	(1)	(3)			1	3
" sideroxylon			1	3	(1)															
" viminalis							(1)	(3)												
" willisii							(1)	(3)	(1)	(3)	(1)	(3)	1	3	1	3	1	3	1	3
TALL SHRUBS *																				
CASUARINACEAE																				
Casuarina stricta	1	3			1	3														
MIMOSACEAE																				
Acacia pycnantha			1	3	(1)	(3)														
" verticillata											1	3								(3)
SANTALACEAE																				
Exocarpus cupressiformis															(1)	(3)				
LICHENS **																				
Cladonia chlorophyaea		3		3																
Cladia aggregata		3		3																
Unidentified spp.				3																3

TABLE 2 (continued)

SITE	A			B			C			
SUBSITE	A1	A2	A3	B1	B2	B3	C1	C2	C3	C4
VEGETATION FORMATION	Closed Heath	Open Scrub	Tall Shrubland	Woodland	Woodland	Woodland/ Closed Scrub	Tall Shrubland/ Woodland	Tall Shrubland/ Woodland	Open Heath	Woodland/ Tall Shrubland
LIVERWORTS **										
Marchantia polymorpha		1 3							1	
Goebelobryum ungiculatum					3				3	
Lethocolea squamata										3
FUNGI **										
Omphalia chromacea	1				(3)				1 (3)	
MOSSES **										
Funaria hygrometrica	3	1 3	3		3	3			3	
Ceratodon purpureus	3	3	3		3	3			3	
Polytrichum juniperinum									3	
Tortella calycina	3	3			3					
Campylopus introflexus	3				3	3		3		
Bryum pachytheca	3									
Unidentified spp.	3	3	3	3	3	3	3	3	3	

SITE	A			B			C			
SUBSITE	A1	A2	A3	B1	B2	B3	C1	C2	C3	C4
VEGETATION FORMATION	Closed Heath	Open Scrub	Tall Shrubland	Woodland	Woodland	Woodland/ Closed Scrub	Tall Shrubland/ Woodland	Tall Shrubland/ Woodland	Open Heath	Woodland/ Tall Shrubland
FERNS and allies **										
LYCOPODIACEAE										
Phylloglossum drummondii									3	
DENNSTAEDTIACEAE										
Pteridium esculentum										3
LINDSAEACEAE										
Lindsaea linearis		(3)			(3)					1 3
SCHIZAEACEAE										
Schizea aspera								(3)		1 3
" bifida					(3)					
" fistulosa						(1) (3)				
SELAGINELLACEAE						(1) (3)				
Selaginella uliginosa						(1) 3		(1) 3	(1) 3	
CENTROLEPIDACEAE										
Centrolepis aristata	1 3		1						1 3	
" strigosa		(3)		(1) (3)					(3)	
SEDGES AND RUSHES **										
CYPERACEAE										
Baumea acuta						(1) (3)			1 3	
Caustis restiacea					(3)					
Cyperus tenellus	(1) (3)				(3)					
Gahnia radula	(1) (3)	1 3	(1) (3)	1 3	1 3	1 3	1 3	1 3	1 3	1 3

TABLE 2 (continued)

SITE	A						B						C							
SUBSITE	A1		A2		A3		B1		B2		B3		C1		C2		C3		C4	
VEGETATION FORMATION	Closed Heath		Open Scrub		Tall Shrubland		Woodland		Woodland		Woodland/ Closed Scrub		Tall Shrubland/ Woodland		Tall Shrubland/ Woodland		Open Heath		Woodland/ Tall Shrubland	
SEDGES AND RUSHES (cont'd)																				
Isolepis inundata	1																1			
" marginata	1																			
Lepidosperma concavum	1	3	1	3	1	3														
" filiforme																	(1)	(3)	(1)	(3)
" neesii													1	3						
" semiteres	1	3	1	3	1	3	1	3		(3)			1	3					1	3
Schoenus apogon	1	3	1	3	1	3				(3)			1	3						
" breviculmis	1	3	1	3	1	3	(1)	(3)					1	3						
" brevifolius											(1)	(3)								
" tenuissimus									1	3	1	3								
Tricostularia pauciflora													1	3	1	3	1	3	1	3
JUNCACEAE																				
Juncus bufonius																			(1)	(3)
" pauciflorus				(3)											(1)	(3)				
" planifolius											(1)	(3)								
RESTIONACEAE																				
Empodisma minus											1	3								
Hypolaena fastigiata								(3)	1	3	1	3	1	3	1	3	1	3	1	3

TABLE 2 (continued)

SITE	A			B			C			
SUBSITE	A1	A2	A3	B1	B2	B3	C1	C2	C3	C4
VEGETATION FORMATION	Closed Heath	Open Scrub	Tall Shrubland	Woodland	Woodland	Woodland/ Closed Scrub	Tall Shrubland/ Woodland	Tall Shrubland/ Woodland	Open Heath	Woodland/ Tall Shrubland
GRASSES **										
GRAMINEAE										
. Aira caryophylla		3								
Agrostis avenacea	(3)	(3)								
. " capillaris										(3)
Amphipogon strictus	1 3	1 3					1 3		1 3	
. Briza minor									(3)	
Danthonia caespitosa		(1)								
" geniculata	(3)	(3)	1 (3)							
" induta	1	1	1	(1)	(1)					
" pilosa		(1)	1							
" procera		(1)								
" semiannularis		(1)								
" setacea	1 3	1 3	1 3	1 3	(1)	(1)	1 3			1 3
" tenuoir		(1)								
Deyeuxia densa						(1)				
" minor							(1)			
" quadriseta		(1)	(1)	1		(1)	(1)			
Dichelachne crinata	(1)	(1)								
" rara						(1)				
Holcus lanatus	(1)	(1)							(1)	
Microlaena stipoides	(1)	(1)		(1)						
Poa morrisii						1 3				
" sieberiana		1 3								
Stipa semibarbata	1 3	1 3	1 3	1 3	(1)		1 3			

TABLE 2 (continued)

SITE	A						B						C							
SUBSITE	A1		A2		A3		B1		B2		B3		C1		C2		C3		C4	
VEGETATION FORMATION	Closed Heath		Open Scrub		Tall Shrubland		Woodland		Woodland		Woodland/ Closed Scrub		Tall Shrubland/ Woodland		Tall Shrubland/ Woodland		Open Heath		Woodland/ Tall Shrubland	
GRAMINEAE (cont'd)																				
Tetrarrhena distichophylla			(1)	(3)									1	3	(1)					
Themeda australis			(1)																	
. Vulpia myuros			1	3														3		
Unidentified Grasses	1	3	1	3	1		1	3			1			3	1		1	3	1	3
ORCHIDS **																				
ORCHIDACEAE																				
Acianthus caudatus	(1)		1	(3)	1	(3)			(1)				(1)							
" exertus	1	(3)		3		3			(1)				1	3						
Caladenia cardiochila	(1)		1	(3)			1		(1)				(1)						(1)	(3)
" carnea	(1)								(1)				(1)							
" deformis	(1)								(1)				1	(3)						
" dilatata	1	(3)				3	1	3	(1)				(1)							
" menziesii	(1)	(3)							(1)		(1)	(3)	1	3						
" patersonii													(1)							
" pusilla	1	3							(1)				(1)							
Calaena major							(1)		(1)	3					(1)					
Calochilis campestris									(1)		(1)		(1)							
" robertsonii									(1)		(1)		(1)							
Chiloglottis reflexa										(3)										
Cyrtostylis reniformis				(3)		(3)			(1)				(1)							
Diuris longifolia	1	(3)		(3)		(3)	1	(3)	(1)				(1)	(3)	(1)					
" maculata													1	(3)						
Eriochilus cucullatus	(1)								1		1	3	(1)				(1)	(3)	1	(3)

TABLE 2 (continued)

SITE	A						B						C							
SUBSITE	A1		A2		A3		B1		B2		B3		C1		C2		C3		C4	
VEGETATION FORMATION	Closed Heath		Open Scrub		Tall Shrubland		Woodland		Woodland		Woodland/ Closed Scrub		Tall Shrubland/ Woodland		Tall Shrubland/ Woodland		Open Heath		Woodland/ Tall Shrubland	
ORCHIDS (Cont'd) **																				
Glossodia major	(1)	(3)	1	3			1	(3)	1	(3)	1	3	1					(3)		
Leporella fimbriata													1	(3)	(1)	(3)				
Lyperanthus nigricans							1	3	1	3					(1)	(3)				
Microtis parviflora	(1)				1								(1)							
" unifolia	1		(1)										(1)							
Orthoceras strictum	(1)				1		(1)		(1)				(1)							
Prasophyllum despectans									(1)											
" elatum									(1)				(1)							
" morrisii	1	(3)		(3)	1	(3)			(1)				1	(3)		(3)				(3)
" odoratum	1								(1)				1							
Pterostylis longifolia	(1)		(1)	(3)					(1)				(1)							
" nana		(3)		(3)	1				(1)				(1)							
" nutans			(1)																	
" parviflora	1	(3)		(3)	1		1		(1)				1	3	(1)					
" plumosa	1	(3)				3		3												
" vittata													(1)							
Thelymitra antennifera	1	3		3		3	1	(3)	1			(3)	1	3	(1)		1	3	1	
" flexuosa		(3)				3	(1)													
" fusco-lutea	(1)	(3)			(1)	(3)														
" ixioides		(3)		3	1		(1)		(1)				(1)				(1)			
" pauciflora	1						1	3	(1)				(1)							
" rubra	1	(3)						(3)	(1)			3								
Thelymitra spp.	1	3		3	1	3	1													

TABLE 2 (continued)

SITE	A						B						C							
SUBSITE	A1		A2		A3		B1		B2		B3		C1		C2		C3		C4	
VEGETATION FORMATION	Closed Heath		Open Scrub		Tall Shrubland		Woodland		Woodland		Woodland/ Closed Scrub		Tall Shrubland/ Woodland		Tall Shrubland/ Woodland		Open Heath		Woodland/ Tall Shrubland	
LILIES AND IRISES **																				
LILIACEAE																				
Burchardia umbellata	1	3	1	3	1	3	1		1	3			1	3	(1)	3	1	3	1	3
Caesia parviflora	1	3										3		3			1			
Chamaescilla corymbosa	1	3	1		1							3	1	3	1	3	1	3	1	3
Dianella revoluta			(1)	(3)			(1)	(3)	(1)	(3)									(1)	(3)
Dichopogon strictus	(1)		(1)										1							
Laxmannia sessiliflora	1	3	1	3	1	3	1	3	1	3	1	3	1	3	1	3	1	3	1	3
Lomandra filiformis	(1)	(3)	1	3	1	3	1	3	(1)	3	1	3	1	3	1	3	1	3	1	3
" longifolia									1	3										
" micrantha			(1)	(3)																
" multiflora				(3)	1														(1)	
Thysanotus juncifolius	(1)	3	(1)																	
" patersonii	1	3	1	3	1	3	1	3	1				1	3					1	3
" tuberosus	(1)		(1)						1					3						
Wurmbea dioica	(1)		(1)										1							
Xanthorrhoea australis			1	3			(1)	(3)	1	3	1	3	1	3	1	3		(3)	1	3
" minor											(1)	(3)								

TABLE 2 (continued)

SITE	A			B			C			
SUBSITE	A1	A2	A3	B1	B2	B3	C1	C2	C3	C4
VEGETATION FORMATION	Closed Heath	Open Scrub	Tall Shrubland	Woodland	Woodland	Woodland/ Closed Scrub	Tall Shrubland/ Woodland	Tall Shrubland/ Woodland	Open Heath	Woodland/ Tall Shrubland
LILIES AND IRISES (cont'd)										
HYPOXIDACEAE										
Hypoxis glabella		(1)			(1)		(1)			
IRIDACEAE										
Patersonia fragilis	(1) (3)	(1) (3)				1 3			1 3	
" occidentalis		(1) (3)				1 3			(1) (3)	
SHRUBS **										
MIMOSACEAE										
Acacia verticillata var. ovoidea						(1) (3)				
" myrtifolia		(1) (3)			(1) (3)		1 3			1 3
" suaveolens				1 3	(1) (3)		1 3	1 3	1 3	1 (3)
EPACRIDACEAE										
Acrotriche serrulata	1 3	(1) 3	(1) 3	1 3	(1) 3	1 3				
Astroloma humifusum	1 3			(3)			(3)			
Brachyloma ciliatum				(1) (3)						
Epacris impressa	1 3	1 3	1 3	1 3	1 3	1 3	1 3	1 3	1 3	1 3
Lissanthe strigosa			(1) (3)							
Leucopogon australis						(1) (3)				
" virgatus	1 3	1 3	1 3	(1) 3	1 3	(1) 3	1 3	(3)		(3)

TABLE 2 (continued)

SITE	A						B						C							
SUBSITE	A1		A2		A3		B1		B2		B3		C1		C2		C3		C4	
VEGETATION FORMATION	Closed Heath		Open Scrub		Tall Shrubland		Woodland		Woodland		Woodland/ Closed Scrub		Tall Shrubland/ Woodland		Tall Shrubland/ Woodland		Open Heath		Woodland/ Tall Shrubland	
SHRUBS **																				
EPACRIDACEAE (cont'd)																				
Monotoca scoparia	1	3	1	3	(1)	3	(1)	(3)	1	3	(1)	3	1	3	(1)	3				
Sprengelia incarnata											1	3								
FABACEAE																				
Aotus ericoides									1	3	(1)	3			(1)	3				
Bossiaea prostrata		3																		
Daviesia brevifolia		(3)		(3)		(3)								(3)						
Dillwynia glaberrima							(1)	(3)	1	3	1	3			1	3	1	3	1	3
" hispida		(3)		(3)	1	3														
" sericea	1	3	1	3	1	3	1	3					1	3						
Gompholobium ecostatum	1	3	1	3	1	3	1	3					1	3						
Hovea linearis				(3)	1	3	1	3												
Platylobium obtusangulum	1	3	1	3	1	3	1	3	(1)	(3)	1	3	1	3	(1)	3	1	3	1	3
Pultenaea daphnoides			(1)	(3)																
" dentata						(3)														
" gunnii										(3)										
" humilis	(1)	(3)	(1)	(3)	(1)	3														
" mollis						3														
" stricta												(3)								
Sphaerolobium vimineum		3		(3)								3		3				3		

TABLE 2 (continu

SITE	A			B			C			
SUBSITE	A1	A2	A3	B1	B2	B3	C1	C2	C3	C4
VEGETATION FORMATION	Closed Heath	Open Scrub	Tall Shrubland	Woodland	Woodland	Woodland/ Closed Scrub	Tall Shrubland/ Woodland	Tall Shrubland/ Woodland	Open Heath	Woodland/ Tall Shrubland
SHRUBS **										
MYRTACEAE										
Baeckea ramosissima ssp. prostrata	3	(3)					3		3	
Leptospermum juniperinum		3		(3)		1 3			1 3	1 3
" myrsinoides	1 3	1 3	1 3	1 3	1 3	1 3	1 3	1 3	1 3	1 3
Melaleuca squarrosa						1 3				
PROTEACEAE										
Banksia marginata	1 3	3	3	(1) (3)	1 3	1 3	1 3	1 3	(3)	1 3
Conospermum mitchellii									(1) 3	
Hakea repullulans							1 3			
" ulicina		(3)		(3)			1 3			
Isopogon ceratophyllus	1 3	1 3	1 3	(1) (3)	1 3	(1) 3				
Lomatia ilicifolia		(1) (3)	(1) (3)		(1) (3)					(1) (3)
Persoonia juniperinum		(1) (3)		1 3	1 3	1 3			(1) 3	(1) (3)
RUTACEAE										
Boronia nana								3		3
Correa reflexa			(1) (3)							
CASUARINACEAE										
Casuarina pusilla	1 3	(1) (3)	1 3	(1) (3)		1 3	1 3	(1) 3	1 3	1 (3)
POLYGALACEAE										
Comesperma ericinum						(1) 3				

SITE	A						B						C							
SUBSITE	A1		A2		A3		B1		B2		B3		C1		C2		C3		C4	
VEGETATION FORMATION	Closed Heath		Open Scrub		Tall Shrubland		Woodland		Woodland		Woodland/ Closed Scrub		Tall Shrubland/ Woodland		Tall Shrubland/ Woodland		Open Heath		Woodland/ Tall Shrubland	
SHRUBS (cont'd)																				
RHAMNACEAE																				
<u>Cryptandra tomentosa</u>	(1)	3			(1)	3	(1)	3					(1)	3						
<u>Spyridium parvifolium</u>			(1)	3																
" <u>vexilliferum</u>	1	3	1	3	1	3														
DILLENIACEAE																				
<u>Hibbertia prostrata</u>							(1)	(3)	1	3	1	3	1	3	1	3			1	3
" <u>sericea</u>			(1)	(3)	1	3														
" <u>stricta</u>	1	3	(1)	3	(1)	3	1	3					1				1	3		
GOODENIACEAE																				
<u>Goodenia ovata</u>																	1	3		
STERCULIACEAE																				
<u>Lasiopetalum baueri</u>					(1)	(3)														
<u>Thomasia petalocalyx</u>					1	(3)														
ASTERACEAE																				
<u>Olearia erubescens</u>									(1)	(3)										
" <u>myrsinoides</u>									(1)	(3)										
" <u>ramulosa</u>			(1)	(3)																
" <u>teretifolia</u>	1	3	1	3	1	3														
THYMELACEAE																				
<u>Pimelia glauca</u>				(3)																
" <u>humilis</u>	1	3	1	3	1	3	(1)	(3)	1	3	1	3	1	3	1	3	1	3	1	3
" <u>linifolia</u>				(3)																
" <u>octophylla</u>	(1)	(3)	(1)	(3)			(1)	3	(1)	(3)			1	3						
" <u>phylicoides</u>		3		3																

TABLE 2 (continued)

SITE	A			B			C			
SUBSITE	A1	A2	A3	B1	B2	B3	C1	C2	C3	C4
VEGETATION FORMATION	Closed Heath	Open Scrub	Tall Shrubland	Woodland	Woodland	Woodland/ Closed Scrub	Tall Shrubland/ Woodland	Tall Shrubland/ Woodland	Open Heath	Woodland/ Tall Shrubland
SHRUBS (cont'd)										
SOLANACEAE										
Solanum laciniatum		(1) (3)								
TREMANDRACEAE										
Tetratheca ciliata	1 3	(1) (3)	3	(3)	1 3	3				
HERBS **										
ROSACEAE										
Acaena anserinifolia		(1) (3)								
ASTERACEAE										
Brachycome uliginosa	1 3	3	1 3						(1) 3	
Craspedia glauca		(1) (3)			(1) (3)		(1) (3)			
Cirsium vulgare									(1) (3)	
Helichrysum obtusifolium	(1) (3)	(1) (3)	(1) 3		(3)	(1) 3	1 3	3	3	1 3
" scorpioides		(3)		3	(3)	3	(3)			
Hypochoeris radicata									1	
Ixodia achillaeoides		(1) 3								
Lagenifera gracilis				1		(1)				
Leptorhynchos linearis							(1)			
" squamatus		(1)								
Gnaphalium sphaericum		(3)							1	
" involucratum		(3)								

TABLE 2 (continued)

SITE	A						B						C							
SUBSITE	A1		A2		A3		B1		B2		B3		C1		C2		C3		C4	
VEGETATION FORMATION	Closed Heath		Open Scrub		Tall Shrubland		Woodland		Woodland		Woodland/ Closed Scrub		Tall Shrubland/ Woodland		Tall Shrubland/ Woodland		Open Heath		Woodland/ Tall Shrubland	
HERBS (cont'd)																				
EUPHORBIACEAE																				
Amperea xiphoclada											1	3		3		3				
Poranthera microphylla											1								1	
DROSERACEAE																				
Drosera auriculata	1	3		3	1	3	1	3	1	3	1	3	1	3	1	3	1	3	1	3
" glanduligera	1	3		3			(1)	(3)	1	3						(3)		(3)		
" macrantha	1	3		(3)		3	1	3	1					3		3				
" peltata	1			3					1	3	1	3						3		
" pygmaea	1	3									1	3	1			(3)	1	3		
" whittakerii	1			3			1		1	3	1	3			1					3
RUBIACEAE																				
Galium binifolium												(3)								
" gaudichaudii												(3)								
Opercularia scabrida								3												
" varia	1	3	1	3	1	3	1	3	1	3	1	3	1	3	1	3	1	3	1	3
HALORAGACEAE																				
Gonocarpus tetragynus	1	3	1	3	1	3	1	3	1	3	1	3	1				1		1	3
" micranthus												(3)								
GOODENIACEAE																				
Goodenia geniculata	1	3	1	3	1	3	1	3				(3)	1			3		3	1	3
" lanata			(1)	(3)			1		1	3	1	3	(1)	3	(1)	3				
Scaevola pallida		(3)				(3)														

TABLE 2 (continued)

SITE	A			B			C			
SUBSITE	A1	A2	A3	B1	B2	B3	C1	C2	C3	C4
VEGETATION FORMATION	Closed Heath	Open Scrub	Tall Shrubland	Woodland	Woodland	Woodland/ Closed Scrub	Tall Shrubland/ Woodland	Tall Shrubland/ Woodland	Open Heath	Woodland/ Tall Shrubland
HERBS (cont'd)										
UMBELLIFERAE										
Hydrocotyle callicarpa		(3)	1	1		(3)				
" sibthorpioides						(3)				
Platysace heterophylla				1 3	1 3	1 3	1	1 3	1 3	1 3
Xanthosia pusilla	1 3	3	1 3	1 3	1 3	1 3	1 3	1 3	1 3	1
" dissecta						(3)				
LOBELIACEAE										
Lobelia gibbosa					(1)	(1) (3)				(1)
" rhombifolia		(3)			(3)		1			
LOGANIACEAE										
Mitrasacme pilosa						(3)				
OXALIDACEAE										
Oxalis corniculata		(3)								(3)
PLANTAGINACEAE										
Plantago varia		(1) (3)								(1) 3
LENTIBULARIACEAE										
Polypompholyx tenella									(1)	
STACKHOUSIACEAE										
Stackhousia monogyna	(1)	(1) (3)					3			
STYLIDIACEAE										
Stylidium graminifolium	(1) 3				(1) 3		1 3	3		
" perpusillum									1 3	

TABLE 2 (continued)

SITE	A			B			C			
SUBSITE	A1	A2	A3	B1	B2	B3	C1	C2	C3	C4
VEGETATION FORMATION	Closed Heath	Open Scrub	Tall Shrubland	Woodland	Woodland	Woodland/ Closed Scrub	Tall Shrubland/ Woodland	Tall Shrubland/ Woodland	Open Heath	Woodland/ Tall Shrubland
HERBS (cont'd)										
VIOLACEAE										
Viola hederacea ssp. sieberiana	1 3	3	3							
CAMPANULACEAE										
Wahlenbergia gracilenta	(1)	(1)		1 3						
" stricta	(1)			1	1					(1)
POLYGALACEAE										
Comesperma calymega	1 3	3	3	3	1 3	1 3	3	3	1	1
GERANIACEAE										
Pelargonium australe	1									
BRUNONIACEAE										
Brunonia australis		(1)			(1)					(1)
CREEPERS & CLIMBERS **										
PITTOSPORACEAE										
Billardiera scandens		(1) 3	1 3			1 3				
LAURACEAE										
Cassytha glabella	1 (3)	1 3	1 3	3	1 3	3	1 3	1 3	1 3	1 3
" melantha		(3)								

TABLE 2 (continued)

SITE	A			B			C			
SUBSITE	A1	A2	A3	B1	B2	B3	C1	C2	C3	C4
VEGETATION FORMATION	Closed Heath	Open Scrub	Tall Shrubland	Woodland	Woodland	Woodland/ Closed Scrub	Tall Shrubland/ Woodland	Tall Shrubland/ Woodland	Open Heath	Woodland/ Tall Shrubland
CREEPERS & CLIMBERS (cont'd)										
POLYGALACEAE										
Comesperma volubile	1 3									
FABACEAE										
Kennedia prostrata	1	(1) 3		3						
Trifolium ssp.									1	
SEEDLINGS										
Monocotyledon	1	1	1	1	1	1	1	1	1	1
Dicotyledon	1	1	1	1	1	1	1	1	1	1
TOTAL SPECIES	107	134	86	80	99	86	100	53	69	64

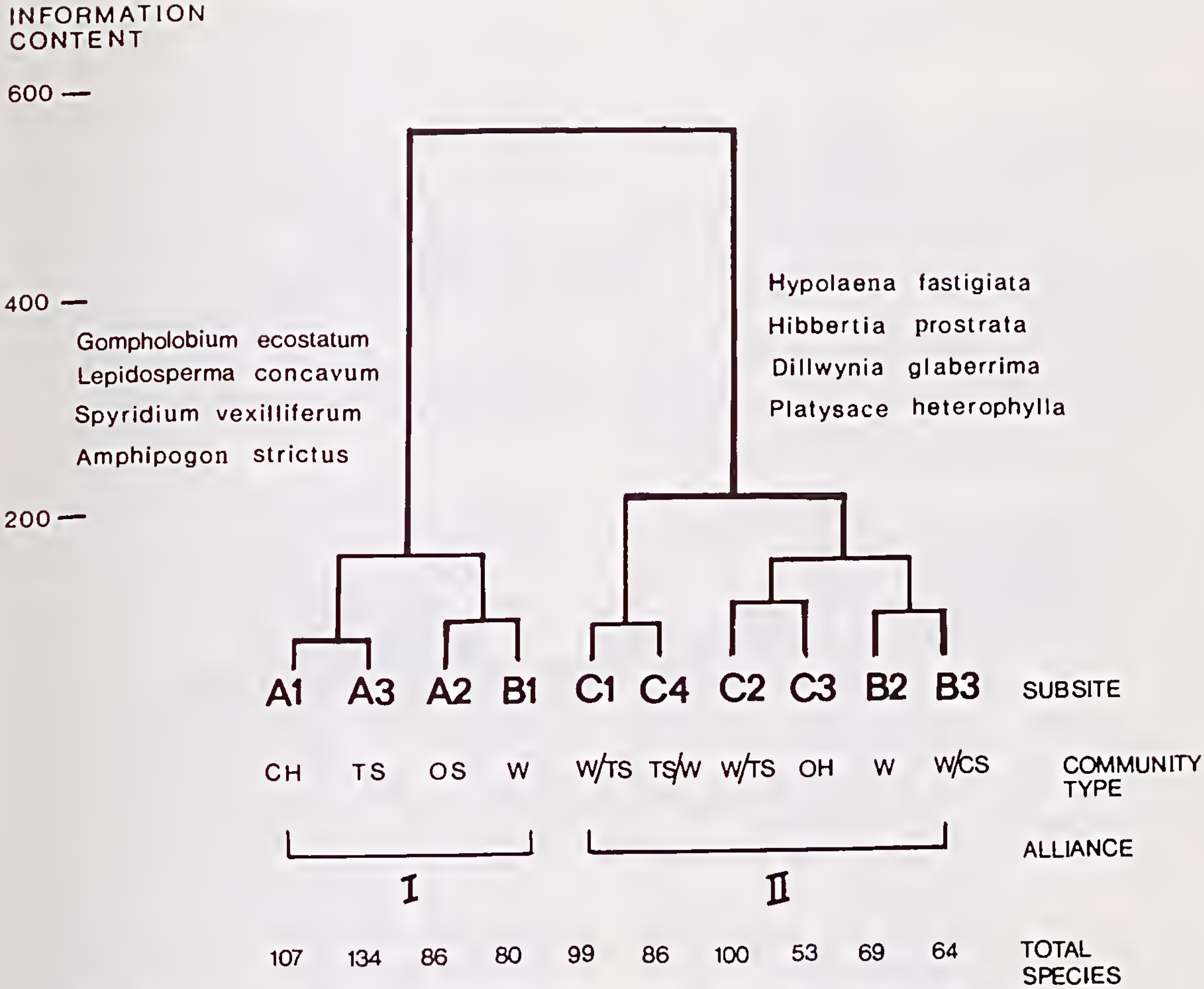


Fig. 2—Dendrogram showing hierarchical classification of the vegetation communities studied. Computer packages used were GCOM and MACINF. Species associating with the two main alliances are indicated. Vegetation structural types are: CH=closed heath, OS=open scrub, TS=tall shrubland, W=woodland, CS=closed scrub, OH=open heath.

changed little in the first three years after fire. Ninety percent of all species present by the third year appeared in the first year after fire (Table 2).

Alliance I (Subsites A1, A2, A3 and B1) was composed of subcommunities containing *Amphipogon strictus*, *Lepidosperma concavum*, *Gompholobium ecostatum* and *Spyridium vexilliferum*, and included closed heath, scrub, tall shrubland and woodland structural types. Some species associated with Alliance I (e.g. *Gompholobium ecostatum*) occurred only at sites where soils contained iron nodules and were derived from the Demon's Bluff Formation (Tables 1, 2, Fig. 6).

The subcommunities of Alliance II (subsites B2, B3, C1, C2, C3, C4) contained *Hypolaena fastigiata*, *Hibbertia prostrata*, *Dillwynia glaberrima* and *Platysace heterophylla* (Fig. 2). All occurred on sandy or gravelly soils (Tables 1, 2, Fig. 6), and included tall shrubland and woodland and open heath structural types.

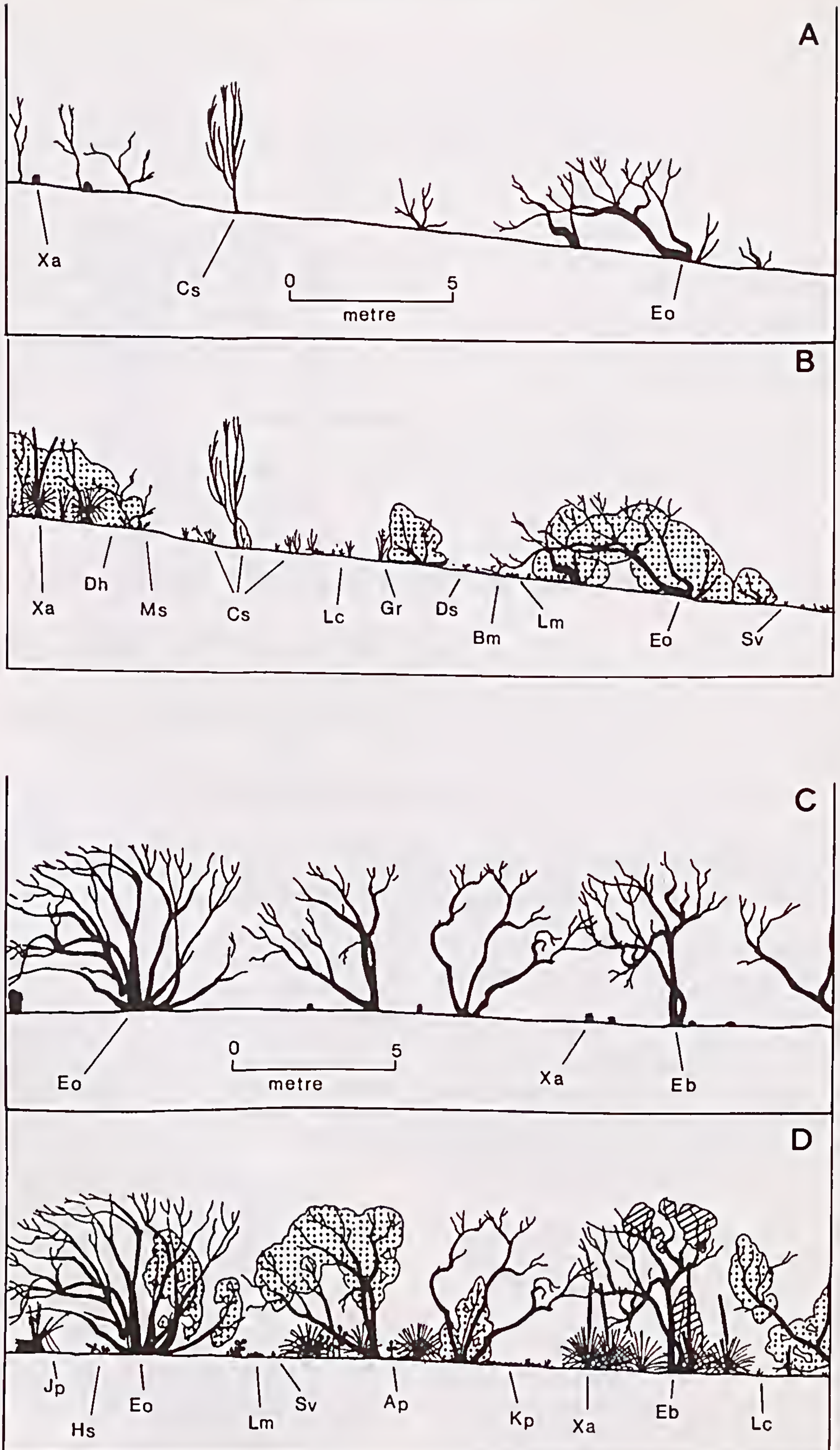
The distinct floristic differences between some subcommunities appeared to reflect variations in drainage, soils and topography. Different species of sedge or rush were commonly associated with communities on certain types of soil and topography. Communities on peaty soils in depressions or along drainage lines almost always contained *Gahnia radula* and the shrub *Leptospermum juniperinum*. Communities on clayey or loamy soils contained varying proportions of *Schoenus breviculmis*, *Lepidosperma semiteres* or *Lepidosperma neesii*. Communities on sandy or gravelly soils all contained *Hypolaena fastigiata*.

Structure

The fire completely incinerated the understorey at all sites, and killed the top 0.9–2.8 m of the eucalypt canopy. Very small trees (girth <10 cm) were burnt to the ground.

The overstorey and understorey at all sites re-established in the first three years after fire (Figs 3, 4). Approximate rate of recovery of canopy height (relative to the original height) was faster than the rate of recovery of canopy percentage cover. In contrast, rate of recovery of understorey percentage cover (relative to the original percentage cover) was faster than the rate of recovery of understorey height (Fig. 5).

Ninety percent of eucalypts survived the fire and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Sv
Ap
Kp
Xa
Eb
Lc

vegetative regrowth commenced within 2-3 months. *Eucalyptus obliqua* of girth at breast height greater than 0.5 m pre-fire, generally sprouted from trunk and crown epicormic buds, whereas trees of less than 0.3 m sprouted from the lignotuber only. Stem mortality was high in open scrub (Fig. 3), where fire intensities had been high. Here, over 60% of all multiple stems were killed. No significant changes in girth were observed in the first 3 years after fire. In shrubland and scrub communities basal epicormics of eucalypts contributed significantly to the vegetation cover during years one to three. By three years, the percentage recovery of canopy height in heath woodland was 77-100% in crown fired and 84-100% in crown scorched eucalypts (mean 90% for all). Percentage recovery of canopy cover was 66% for most communities, less in scrub and at dry sites (range 28-100%, mean 61% for all, Table 3).

Salt spray affected overstorey height and cover recovery at site A. Here, young regrowth on the seaward side of *E. obliqua* (Fig. 3a) was killed by chloride toxicity. Height recovery of *Leptospermum myrsinoides* and *Monotoca scoparia* in the heathy understorey was similarly affected.

During understorey recovery, mean percentage cover of bare ground decreased from 98% at year one, to 39% at year three (Fig. 7). Understorey height at three years differed between subsites (range 0.2-1.0 m, Table 3, Figs 3, 4) and the percentage height recovery (relative to the original height) ranged from 20–67%. Mean percentage height recovery of heath and heath woodland was similar (42.5% c.f. 48.3% by year 3, Fig. 5). Understorey percentage cover at three years also varied between subsites (Table 3, Fig. 6), as did the percentage recovery of this percentage cover (range 28-100%). Mean recovery of cover of the shrub stratum was similar for heath and heath woodland (70% c.f. 78% by year 3, Fig. 5).

Cover of herbs never exceeded 1% in heaths or heath woodlands in the first 3 years following fire (Fig. 7). In contrast, cover of shrubs increased with time and, by year three, formed 67.5% cover in heaths (Fig. 7). Similar shrub cover was seen in the understorey of heath woodlands by year three (Fig. 7). Sedges and rushes were a significant cover component in heaths by year three, as were *Xanthorrhoea australis* and mosses in some heath woodlands (Table 3, Fig. 6). The variation in shrub stratum cover between subsites at three years (Fig. 6) probably reflected differences in fire intensity, eucalypt canopy cover, soil structure, drainage and grazing. With the exception of subsite B1 (disturbed), greatest recovery rate (of both height and percentage cover) was seen in crown-scorched sub-communities (subsites B2, B3, C4, Tables 1, 3) on sloping sites, with gravelly soils of moderate depth.

Regeneration strategies

Regeneration was either by regrowth (from dormant buds, in stems, lignotubers, root tussocks, roots, rhizostolons, rhizomes, corms, tubers and tuberoids), from seed or by both means (Table 4).

The first species to appear following the fire regenerated mainly by regrowth and included *Xanthorrhoea australis* at three weeks, and graminoids and herbs from four to five weeks. Sprouting of shrubs such as *Banksia marginata, Casuarina pusilla, Leptospermum myrsinoides, Monotoca scoparia* and *Platylobium obtusangulum* occurred by three months. By the end of year one, all species capable of vegetative regrowth, and over three-quarters of species which regenerated from seed, had appeared.

Regeneration strategies for all species are presented in Table 4. Species have been grouped using the classification of Purdie (1977a & b) and will be discussed in the text using her terminology. Thirty seven percent of species regenerated only by vegetative regrowth. This group (termed "obligate regrowth regenerators" – ORS – by Purdie 1977), included sedges and rushes, and geophytes such as orchids. Thirty three percent of species regenerated from seed only ("obligate seed regenerators" – OSR). This group was composed mainly of shrubs and herbs. The remaining 30% of species regenerated both vegetatively and from seed ("facultative regrowth regenerators" – FRS). This group included all trees, as well as some shrubs and herbs.

Examination of regeneration strategies of trees and shrubs showed that 54% of all trees and shrubs were either ORS or FRS regenerators. Most FRS shrubs showed a high degree of rootstock regeneration and produced very few seedlings (e.g. *Leptospermum myrsinoides, Banksia marginata*), but some (e.g. *Isopogon ceratophyllus, Platylobium obtusangulum*) regenerated in equal numbers by regrowth or seed. Regeneration from lateral roots and lignotubers as well as from seed occurred in *Casuarina stricta, Eucalyptus willisii* and *Exocarpos cupressiformis*. Shrubs regenerating by regrowth alone were rare, and included *Hakea repullulans, Conospermum mitchellii* and (in other parts of the district) *Grevillea infecunda*.

Forty-six percent of trees and shrubs regenerated only from seed, and often at high density (e.g. *Spyridium vexilliferum* 132 seedlings/m^2, *Epacris impressa* 138 seedlings/m^2, *Hibbertia prostrata* 75 seedlings/m^2. Mortality of seedlings was highest during the dry summer period.

Fig. 3 – Vegetation profiles at site A immediately after the fire and 3 years later. Horizontal and vertical scales are the same. Stippling and hatching indicates the extent of canopy regrowth.
A. Tall shrubland of *Eucalyptus obliqua* (Eo) and *Casuarina stricta* (Cs) immediately after the fire (site A3).
B. Site A3 three years after fire. *Gahnia radula* (Gr), *Banksia marginata* (Bm), *Dillwynia hispida* (Dh), *Dillwynia sericea* (Ds), *Lepidosperma concavum* (Lc), *Leptospermum myrsinoides* (Lm), *Spyridium vexilliferum* (Sv), *Xanthorrhoea australis* (Xa) and *Monotoca scoparia* (Ms) are present in the shrub stratum. Cs has regenerated from lignotubers, root suckers and seed.
C. Open scrub of *Eucalyptus obliqua* (Eo) and *Eucalyptus baxteri* (Eb) immediately after fire. *Xanthorrhoea australis* (Xa) is present in the understorey (Site A2).
D. As for Fig. 3C but three years after fire. *Spyridium vexilliferum* (Sv), *Acacia pycnantha* (Ap) *Juncus pallidus* (Jp), *Hibbertia sericea* (Hs), *Leptospermum myrsinoides* (Lm), *Kennedia prostrata* (Kp) and *Lepidosperma concavum* (Lc) are present in the understorey.

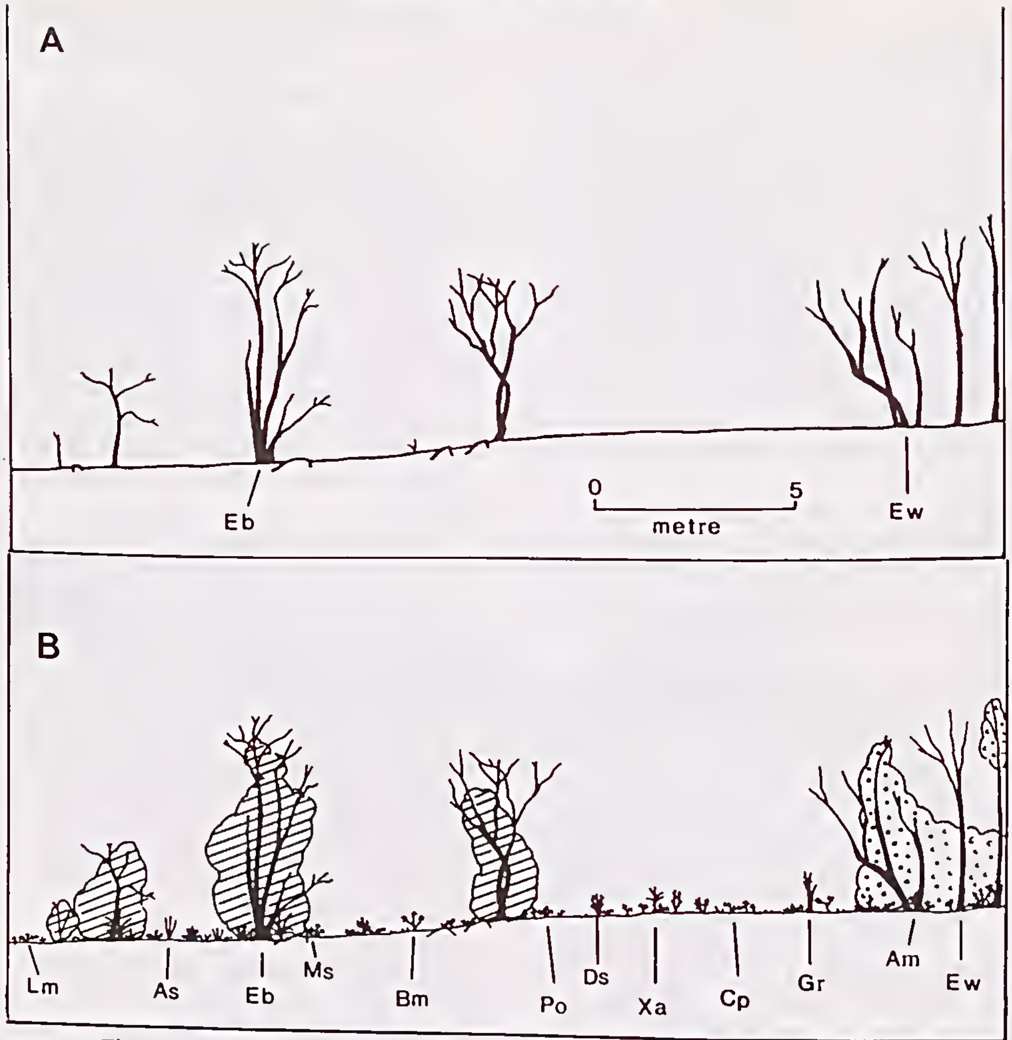


Fig. 4—Vegetation profiles at sites B and C at the time of the fire and 3 years later.
A. *Eucalyptus baxteri* (Eb) and *Eucalyptus willissii* (Ew) woodland/tall shrubland immediately after fire (site C1).
B. As for Fig. 4A, 3 years after fire. *Banksia marginata* (Bm), *Casuarina pusilla* (Cp), *Gahnia radula* (Gr), *Xanthorrhoea australis* (Xa), *Platylobium obtusangulum* (Po), *Leptospermum myrsinoides* (Lm), *Acacia suaveolens* (As), *Acacia myrtifolia* (Am), *Monotoca scoparia* (Ms) and *Dillwynia sericea* (Ds) are present in the understorey.
C. *Eucalyptus obliqua* (Eo) woodland with *Xanthorrhoea australis* (Xa) (site B2).
D. As for Fig. 4C, 3 years after fire. *Banksia marginata* (Bm), *Lepidosperma myrsinoides* (Lm), *Monotoca scoparia* (Ms), *Dillwynia glaberrimma* (Dg), *Epacris impressa* (Ec), *Acacia suaveolens* (As), *Aotus ericoides* (Ae), *Casuarina pusilla* (Cp), *Hypolaena fastigiata* (Hf) and *Leptospermum juniperinum* (Lj) are present in the understorey.

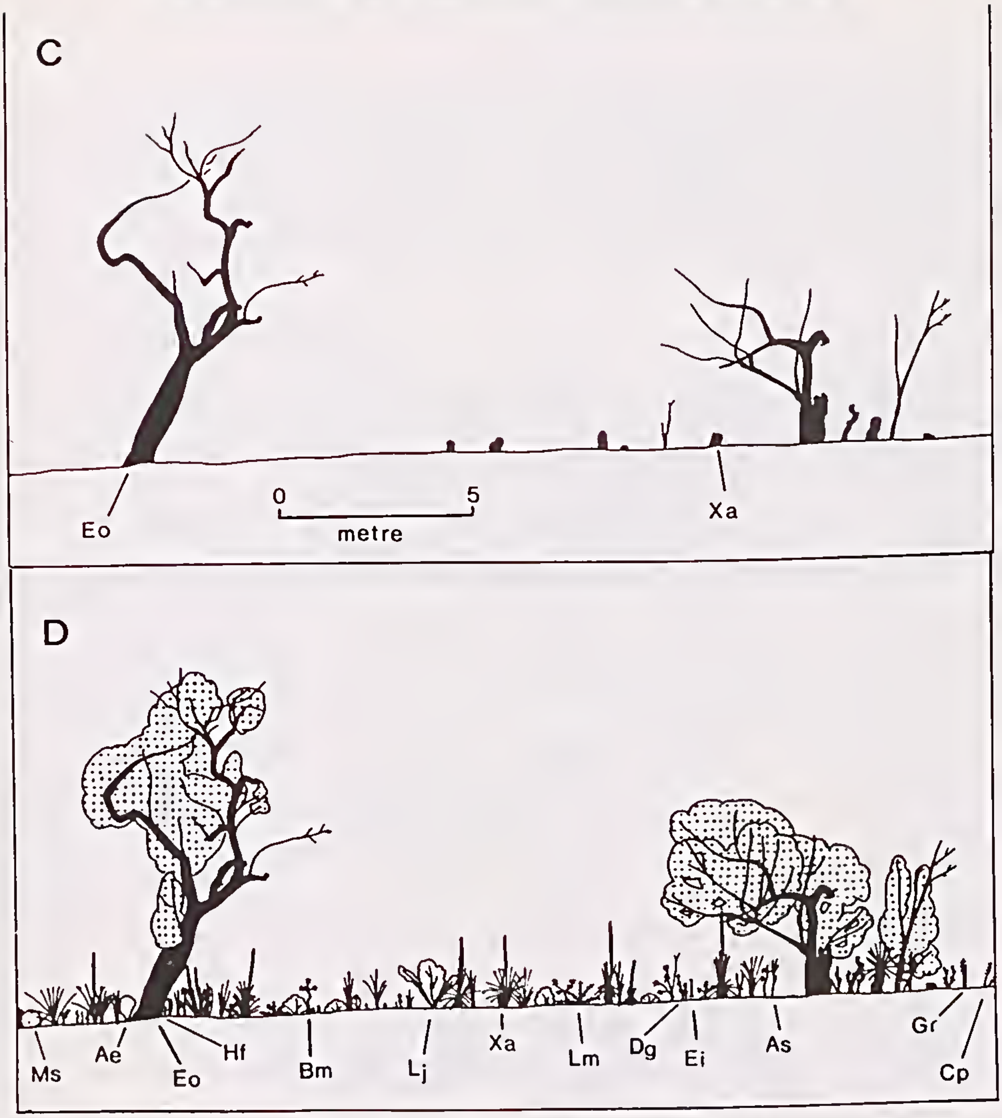
Flowering response after fire

There was a conspicuous flush of herbs the first spring (i.e. 6-8 months) after fire. Fifty three percent of the 227 species regenerating during year one, flowered that year (Table 4). Most (95%) were herbs, and included Droseraceae, Orchidaceae, Liliaceae and Gramineae. All species flowering in the first 4-5 months were ORS herbs and included the autumn and winter flowering orchids, *Eriochilus cucullatus, Prasophyllum morrisii* and *Pterostylis parviflora* as well as *Drosera whittakeri, Brachycome uliginosa* and *Lagenifera gracilis*.

By spring (7 months) tall inflorescences of *Xanthorrhoea australis* were conspicuous at all sites, and huge numbers of orchids, lilies and other herbs were in flower. Many observers commented that colour of many specie[s] appeared more intense than in non-fire years.

Grasses were conspicuous the first spring after fire[.] Twenty one species were identified at site A, including [8] species of *Danthonia*. Some species (e.g. *Danthonia in[un]duta*) flowered prolifically throughout the district and wer[e] not seen in later years.

All 40 species of terrestrial orchids recorded at the site[s] appeared and flowered the first year after fire. Observa[-]tions suggested that the density of flowering of most spe[-]cies was higher than in normal years. No difference i[n] density of flowering of orchids was observed betwee[n] heath and woodland. Flowering of some orchid specie[s] was stimulated by fire. Two species (*Lyperanthus nigri[cans]*



cans and *Caladenia menziesii*), which appear but rarely in flower in normal years, bloomed prolifically the spring after the fire. Another uncommon species, *Caladenia deformis*, which appeared and flowered in huge numbers the first spring, was rarely seen later. Of the 96 species of orchid and 11 orchid hybrids recorded in the district, all but one (*Arthrochilus huntianus*) reappeared and flowered in the first three years after fire. Flowering of some species with tubers close to the surface of the soil (e.g. *Pterostylis nutans*) was reduced following fire. Flowering out of season (spring rather than autumn) occurred in some species (e.g. *Chiloglottis reflexa*). Seed-set accompanied post-fire flowering for all species of orchids. Further information on the post-fire response of orchids will be published separately by M.D.W.

Both number and density of herbaceous species decreased by half in the second and third years after fire. The total number of species of orchids flowering in quadrats decreased from 28 (year 1) to 11 (year 3). Similarly, the number of species of grasses flowering in quadrats declined from 11 (year 1) to 5 (year 3). Density of *Brachycome uliginosa* and *Chamaescilla corymbosa* at subsite A1 decreased by year three to 20% and 44% of year one values, respectively.

Grazing of orchids, lilies and grasses by European rabbits (*Oryctolagus cuniculus*) was observed from year one on coastal heath (subsite A1). Here the number of species of orchids flowering in spring declined from 18 (year 1) to 9 (year 3), and the density of flowering orchids at year three was 22% of that seen at year one. Grazing of the orchid *Thelymitra antennifera* by grey kangaroos (*Macropus giganteus*), occurred on open heath (subsite C3). Like subsite A1, this area was not far from the fire boundary. Here, density of flowering at year three was 70% of that seen in year one, though numbers of non-flowering plants of the same species had increased.

Few shrubs flowered during year one. One conspicuous exception was *Lomatia ilicifolia* which flowered prolifically on regrowth. Approximately 94% of shrubs did not commence flowering till years two or three. By year three, 98% of species (248/252) had flowered including three species of trees and 64 species of shrubs. Not flowering were three species of trees (*Eucalyptus aromaphólia*, *E. baxteri* and *E. viminalis*) and two species of tall scrubs

TABLE 3
STRUCTURE OF PLANT COMMUNITIES — 3 YEARS AFTER FIRE

SUBSITE	A1	A2	A3	B1	B2	B3	C1	C2	C3	C4
VEGETATION TYPE	CH	OS	TS	W	W	W/CS	W/TS	TS/W	OH	W/TS
EUCALYPTS *										
(SPECIES)	-	EO**	EO	EO	EO	EO	EB	EW	-	EO
COVER %										
Prefire (approx.)	-	30-70	10-30	10-30	10-30	10-30 ·	10-30	10-30	-	10-30
3 years	-	20	20	20	20	20	10	20	-	10-30
Height (m)										
Prefire (approx.)	-	4.4	2.5	11.7	11.8	10.4	6.2	4.6	-	7.5
Length killed	-	1.4	2.1	2.2	2.8	2.9	2.3	0.9	-	1.2
3 years	-	3.7	2.25	10.7	10.3	8.7	4.8	5.1	-	7.5
Length of Epicormics (m)										
3 years { Base	-	1.6	} 2.2	1.2	0	0	1.3	2.1	-	0.2
3 years { Trunk	-	1.0		0.8	1.0	1.5	1.2	1.5	-	1.2
3 years { Crown	-	0.7	1.8	1.2	1.2	1.2	0.9	1.4	-	1.1
UNDERSTOREY										
COVER %										
Prefire (approx.) - all plants	70-100	30-70	30-70	30-70	30-70	30-70	30-70	30-70	30-70	30-70
3 years { all plants	64	61	57	20	75	92	30	60	60	80
3 years { shrubs	47	25	32	15	51	71	20	53	42	55
3 years { moss	-	10	-	-	1.5	-	-	-	-	-
3 years { <u>Xanthorrhoea</u>	-	13	-	-	21	10	-	4	-	2
3 years { bare ground	36	39	43	80	25	8	70	40	40	20
Height (m)										
Prefire - approx.	0.5	1.0	0.5	0.5	1.5	1.5	0.5	1.5	2.0	1.5
Length killed	0.5	1.0	0.5	0.5	1.5	1.5	0.5	1.5	2.0	1.5
3 years	0.2	0.2	0.2	0.2	1.0	0.8	0.2	0.9	0.9	1.0

* Tallest stratum ** EO = <u>E. obliqua</u> EB = <u>E. baxteri</u> EW = <u>E. willisii</u>

TABLE 4

REGENERATION STRATEGIES AND FLOWERING 1-3 YEARS AFTER FIRE

Key: Regeneration Strategy/Year:- S1 = germinated from seed year 1; S2 = germinated from seed year 2; S3 = germinated from seed year 3; R1 = regrowth from rhizomes year 1; R2 = regrowth from rhizomes year 2; T1 = regrowth from tubers year 1; Tu = regrowth from tuberoids year 1; L1 = regrowth from lignotubers year 1; St1 = regrowth from stems year 1; C1 = regrowth from corms year 1; RSt1 = regrowth from rhizostolons year 1; Rsk1 = regrowth from root suckers year 1
Flowering/Year:- F1 = first flowered year 1; F2 = first flowered year 2; F3 = first flowered year 3

* Terminology follows Purdie (1977a,b)

OBLIGATE SEED REGENERATORS * (from seed or propagules only)

	Regen. Strategy	First Flowering
TALL SHRUBS		
Acacia pycnantha	S1	F2
" verticillata	S1	F2
LICHENS		
Cladia aggregata	S2	
Cladonia chlorophyaea	S2	F3
LIVERWORTS		
Goebelobryum unguiculatum	S3	
Lethocolea squamata	S3	F3
Marchantia polymorpha	S1	F1
FUNGI		
Omphalia chromacea	S1	F1
MOSSES		
Bryum pachytheca	S3	F3
Camphylopus introflexus	S3	F3
Ceratodon purpureus	S2	F2
Funaria hygrometrica	S1	F1
Polytrichum juniperinum	S3	F3
Tortella calycina	S3	F3

FACULTATIVE REGROWTH REGENERATORS * (by regrowth, and from seed or propagules)

	Regen. Strategy		First Flowering
TREES			
Eucalyptus aromaphloia	St1, L1	S1	
" baxteri	St1, L1	S1	
" obliqua	St1, L1	S1	F2
" sideroxylon	St1, L1	S1	F3
" viminalis	St1, L1	S1	
" willisii	St1,L1, Rst 1	S2	F3
TALL SHRUBS			
Casuarina stricta	L1, Rsk1	S2	
Exocarpus cupressiformis	L1, Rsk1	S1	
FERNS and Allies			
Centrolepis aristata	R1	S1	F1
" strigosa	R1	S1	F1
Pteridium esculentum	R1	S2	F2
GRASSES			
Agrostis averacea	R1	S1	F1
Amphipogon strictus	R1	S1	F1
Danthonia caespitosa	R1	S1	F1
" geniculata	R1	S1	F1
" induta	R1	S1	F1
" pilosa	R1	S1	F1
" procera	R1	S1	F1
" semiannularis	R1	S1	F1
" setacea	R1	S1	F1
" tenuoir	R1	S1	F1

OBLIGATE REGROWTH REGENERATORS * (by regrowth only)

	Regen. Strategy	First Flowering
FERNS and Allies		
Phylloglossum drummondii	R2	F2
Lindsaea linearis	R1	F2
Schizea aspera	R1	F2
" bifida	R1	F2
" fistulosa	R1	F2
Sellaginella uliginosa	R1	F2
SEDGES AND RUSHES		
Baumea acuta	R1	F1
Caustis restiacea	R1	F3
Cyperus tenellus	R1	F1
Gahnia radula	R1	F2
Isolepis inundata	R1	F1
" marginata	R1	F1
Lepidosperma concavum	R1	F2
" filiforme	R1	F2
" neesii	R1	F2
" semiteres	R1	F2
Schoenus apogon	R1	F1
" breviculmis	R1	F2
" brevifolius	R1	F2
" tenuissimis	R1	F2
Tricostularia pauciflora	R1	F2
Juncus bufonius	R1	F2
" pauciflorus	R1	F2
" planifolius	R1	F2
Empodisma minus	R1	F2
Hypolaena fastigiata	R1	F2

TABLE 4 (continued)

OBLIGATE SEED REGENERATORS * (from seed or propagules only)	Regen. Strategy	First Flowering
GRASSES		
Aira caryophylla	S1	F1
Agrostis avenacea	S1	F1
Briza minor	S1	F1
Vulpia myuros	S1	F1
SHRUBS		
Acacia myrtifolia	S1	F2
" suaveolens	S1	F2
" verticillata var. ovoidea	S1	F2
Baeckea ramosissima ssp. prostrata	S1	F1
Boronia nana var. nana	S2	F2
Bossiaea prostrata	S1	F2
Comesperma ericinum	S1	F2
Epacris impressa	S1	F2
Gompholobium ecostatum	S1	F2
Goodenia ovata	S1	F1
Hakea ulicina	S1	F2
Hibbertia prostrata	S1	F1
Lasiopetalum baueri	S1	F2
Olearia erubescens	S1	F2
" myrsinoides	S1	F2
" ramulosa	S1	F2
" teretifolia	S1	F2
Pimelia glauca	S2	F2
" humilis	S1	F1
" linifolia	S2	F2
" octophylla	S1	F1
" phylicoides	S2	F2

FACULTATIVE REGROWTH REGENERATORS * (by regrowth, and from seed or propagules)	Regen. Strategy		First Flowering
GRASSES (cont'd)			
Deyeuxia densa	R1	S1	F1
" minor	R1	S1	F1
" quadriseta	R1	S1	F1
Dichelachne crinata	R1	S1	F1
" rara	R1	S1	F1
Holcus lanatus	R1	S1	F1
Microlaena stipoides	R1	S1	F1
Poa morrisii	R1	S1	F1
" sieberiana	R1	S1	F1
Stipa semibarbata	R1	S1	F1
Tetrarrhena distichophylla	R1	S1	F1
Themeda australis	R1	S1	F1
LILIES and IRISES			
Patersonia fragilis	R1	S2	F1
" occidentalis	R1	S2	F1
Xanthorrhoea australis	St1	S1	F1
" minor	St1	S1	F1
SHRUBS			
Acrotriche serrulata	L1	S1	F2
Aotus ericoides	L1	S1	F2
Astroloma humifusum	L1	S1	F2
Banksia marginata	L1	S ?	F2
Brachyloma ciliatum	L1	S1	F2
Casuarina pusilla	L1	S1	F2
Correa reflexa	L1	S1	F2
Cryptandra tomentosa	L1	S1	F2

OBLIGATE REGROWTH REGENERATORS * (by regrowth only)	Regen. Strategy	First Flowering
ORCHIDS		
Acianthus caudatus	Tu1	F1
" exsertus	Tu1	F1
Caladenia cardiochila	Tu1	F1
" carnea	Tu1	F1
" deformis	Tu1	F1
" dilatata	Tu1	F1
" menziesii	Tu1	F1
" patersonii	Tu1	F1
" pusilla	Tu1	F1
Calaena major	Tu1	F1
Calochilis campestris	Tu1	F1
" robertsonii	Tu1	F1
Cyrtostylis reniformis	Tu1	F1
Diuris longifolia	Tu1	F1
" maculata	Tu1	F1
Eriochilus cucullatus	Tu1	F1
Glossodia major	Tu1	F1
Leporella fimbriata	Tu1	F1
Lyperanthus nigricans	Tu1	F1
Microtis parviflora	Tu1	F1
" unifolia	Tu1	F1
Orthoceras strictum	Tu1	F1
Prasophyllum despectans	Tu1	F1
" elatum	Tu1	F1
" morrisii	Tu1	F1
" odoratum	Tu1	F1
Pterostylis longifolia	Tu1	F1
" nana	Tu1	F1
" nutans	Tu1	F1
" parvifolia	Tu1	F1
" plumosa	Tu1	F1
" vittata	Tu1	F1

TABLE 4 (continued)

OBLIGATE SEED REGENERATORS * (from seed or propagules only)		
	Regen. Strategy	First Flowering
SHRUBS (cont'd)		
Pultenaea daphnoides	S1	F2
" dentata	S2	F2
" gunnii	S2	F2
" humilis	S2	F2
" mollis	S2	F2
" stricta	S2	F2
Solanum laciniatum	S1	F2
Sphaerolobium vimineum	S2	F2
Sprengelia incarnata	S1	F2
Spyridium parvifolium	S1	F2
" vexilliferum	S1	F2
Tetratheca ciliata	S1	F1
HERBS		
Acaena anserinifolia	S1	F1
Billardiera scandens	S1	F3
Cassytha glabella	S1	F2
" melantha	S2	F2
Cirsium vulgare	S1	F1
Comesperma calymega	S1	F1
" volubile	S2	F2
Galium binifolium	S1	F2
" gaudichaudi	S1	F2
Gnaphalium involucratum	S1	F2
" sphaericum	S1	F1
Gonocarpus micranthus	S2	F2
" tetragynus	S1	F1
Helichrysum obtusifolium	S1	F2

FACULTATIVE REGROWTH REGENERATORS * (by regrowth, and from seed or propagules)			
	Regen. Strategy		First Flowering
SHRUBS (cont'd)			
Daviesia brevifolia	L1	S1	F2
Dillwynia glaberrima	L1	S1	F2
" hispida	L1	S1	F2
" sericea	L1	S1	F2
Hibbertia sericea	L1	S1	F2
" stricta	L1	S1	F2
Hovea linearis	L1	S1	F2
Isopogon ceratophyllus	L1	S1	F2
Leptospermum juniperinum	L1	S1	F2
" myrsinoides	L1	S1	F2
Leucopogon australis	L1	S2	F2
" virgatus	L1	S2	F2
Lissanthe strigosa	L1	S2	F2
Lomatia ilicifolia	L1	S1	F2
Melaleuca squarrosa	L1	S1	F2
Monotoca scoparia	L1	S1	F2
Persoonia juniperinum	L1	S1	F2
Platylobium obtusangulum	L1	S1	F2
Thomasia petalocalyx	L1	S1	F2
HERBS			
Amperea xiphoclada	R1	S1	F1
Craspedia glauca	R1	S1	F1
Brunonia australis	R1	S1	F1
Goodenia geniculata	R1	S1	F1
" lanata	R1	S1	F1
Helichrysum scorpioides	R1	S1	F1

OBLIGATE REGROWTH REGENERATORS * (by regrowth only)		
	Regen. Strategy	First Flowering
ORCHIDS (cont'd)		
Thelymitra antennifera	Tu1	F1
" flexuosa	Tu1	F1
" fusco-lutea	Tu1	F1
" ixiodes	Tu1	F1
" pauciflora	Tu1	F1
" rubra	Tu1	F1
LILIES and IRISES		
Burchardia umbellata	T1	F1
Caesia parviflora	T1	F1
Chamaescilla corymbosa	T1	F1
Dianella revoluta	T1	F2
Dichopogon strictus	T1	F1
Hypoxis glabella	C1	F1
Laxmannia sessiliflora	T1	F1
Lomandra filiformis	T1	F1
" longifolia	T1	F1
" micrantha	T1	F1
" multiflora	T1	F1
Thysanotus juncifolius	T1	F1
" patersonii	T1	F1
" tuberosus	T1	F1
Wurmbea dioica	C1	F1
SHRUBS		
Conospermum mitchellii	L1	F3
Hakea repullulans	L1	F2

TABLE 4 (continued)

OBLIGATE SEED REGENERATORS * (from seed or propagules only)			FACULTATIVE REGROWTH REGENERATORS * (by regrowth, and from seed or propagules)				OBLIGATE REGROWTH REGENERATORS * (by regrowth only)		
	Regen. Strategy	First Flowering		Regen. Strategy		First Flowering		Regen. Strategy	First Flowering
HERBS (cont'd)			HERBS (cont'd)				HERBS		
Hydrocotyle callicarpa	S1	F2	Leptorhynchos linearis	R1	S1	F1	Brachycome uliginosa	R1	F1
" sibthorpioides	S1	F2	" squamatus	R1	S1	F1	Drosera auriculata	T1	F1
Ixodia achillaeoides	S1	F2	Oxalis corniculata	R1	S1	F1	" glanduligera	T1	F1
Kennedia prostrata	S1	F1	Pelargonium australe	R1	S1	F1	" macrantha	T1	F1
Lobelia rhombifolia	S1	F1	Plantago varia	R1	S1	F1	" peltata	T1	F1
Mitrasacme pilosa	S1	F3	Scaevola pallida	R1	S1	F1	" pygmaea	T1	F1
Platysace heterophylla	S1	F1	Lagenifera gracilis	R1	S1	F1	" whittakerii	T1	F1
Poranthera microphylla	S1	F1					Hypochoeris radicata	R1	F1
Opercularia scabrida	S2	F2					Lobelia gibbosa	R1	F1
" varia	S1	F2					Polypompholyx tenella	T1	F1
Viola hederacea ssp. sieberiana	S1	F1					Stackhousia monogyna	R1	F1
Wahlenbergia gracilienta	S1	F1					Stylidium graminifolium	R1	F1
" stricta	S1	F1					" perpusillum	R1	F1
Xanthosia dissecta	S1	F2							
" pusilla	S1	F2							
Trifolium sp.	S1	F1							

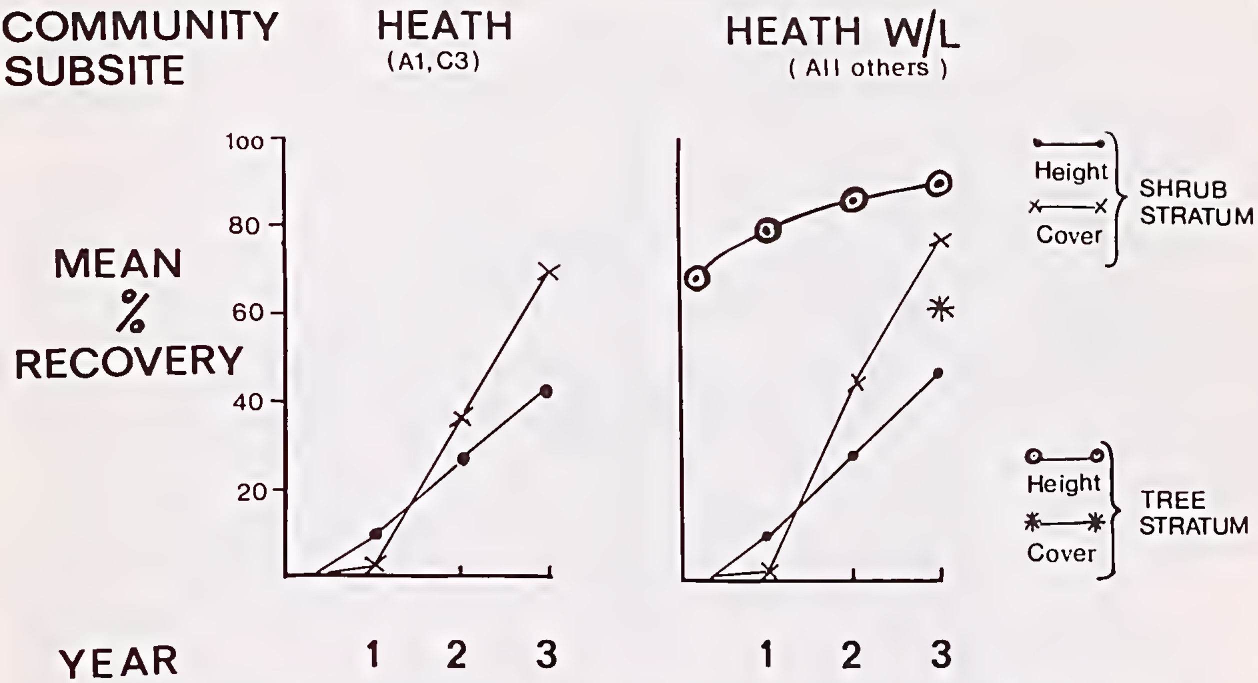


Fig. 5 – Recovery of height and cover of the tree stratum (canopy) and shrub stratum 1-3 years after fire. Heath communities = subsites A1 and C3 combined, heath woodland communities = subsites A2, A3, B1, B2, B3, C1, C2 and C4 combined.

(*Casuarina stricta* and *Exocarpus cupressiformis*).

Very few of the shrubs and eucalypts which flowered during the first 3 years set much seed, and some (e.g. the OSR species, *Hakea ulicina*) set none. Field records showed that, though some shrubs (e.g. *Leptospermum myrsinoides, Banksia marginata*) sprouted and flowered in the first 3 years, their flowers were either not fertilized (*B. marginata*) or fell before seed set (*L. myrsinoides*). Little seed predation was observed in the species which set seed.

Seedlings of some shrubs (*Baeckea ramosissima prostrata, Epacris impressa* and *Spyridium vexilliferum*) had a brief juvenile phase, flowering when only a few centimetres high, and less than 2 years old. Some (e.g. *Baeckea ramosissima prostrata*) were also short-lived, dying immediately after flowering.

Mosses were not common components of most heaths and woodlands, however, a definite successional pattern was seen in the species which established after fire. This was particularly noticeable in open scrub (Fig. 6, Table 2). *Funaria hygrometrica*, first to appear, was replaced by *Ceratodon purpureus* during year two, then by a greater variety of species including *Tortella calycina, Campylopus introflexus* and *Polytrichum juniperinum*.

DISCUSSION

The flora of the north-eastern Otway Ranges is one of the most species-rich in south-eastern Australia (Beauglehole *et al*. 1977, Parsons *et al*. 1977, Anon 1985). Our study has confirmed a species-richness greater than most Victorian dry and wet heaths (Braithwaite & Gullan 1978, Russell & Parsons 1978) and has also shown wide diversity in the heath woodland communities of the Anglesea area. The diversity seen (86-160 species/hectare) exceeds that described by Parsons & Cameron (1974) for heath woodland/closed heath at Seal Creek, Croajingolong National Park, eastern Victoria (69 species/hectare).

Ten heath or heath woodland subcommunities were identified in the areas monitored in our study. Like other Australian heaths they occurred on sandy, acid, lateritic or ground water podsols (Groves 1979). The low levels of available P, total N, organic C and exchangeable cations we have observed in these soils confirm the observations of Pitt (1981) for heaths and heath woodlands in the eastern Otways. All plant subcommunities differed both floristically and structurally, reflecting variations in proximity to the coast, fire history, topography, soil fertility and structure, drainage and aspect.

The plant pathogen *Phytophthora cinnamomi* was isolated from most sites after the fire. Symptoms of past and recent disease were also seen. Investigations have shown that this pathogen is spread through soil by water (Weste *et al.* 1976) and may survive in soil and plant tissues during fire (Weste 1974).

It appears that *Phytophthora* has already changed and will continue to change the floristics of the Anglesea heaths and heath woodlands (Weste & Marks 1974, Parsons *et al.* 1977). In the *Eucalyptus obliqua* woodland above subsites B2 and B3, an understorey of sedges (*Lepidosperma semiteres, Gahnia radula*) has already replaced sclerophyllous shrubs and *Xanthorrhoea australis*. Similar changes have been described following *Phytophthora* infestation in the nearby Brisbane Ranges (Podger & Ashton 1970, Weste 1974). Whether or not fire has modified the long-term effects of *Phytophthora* (Dawson *et al.* 1985) cannot be established in our study

TABLE 5
SOIL ANALYSIS OF A HORIZON (0–10 cm) 1 & 2 YEARS AFTER FIRE

COMMUNITY	YEAR AFTER FIRE	pH	EXCH. Na ppm	EXCH. K ppm	EXCH. Ca ppm	EXCH. Mg ppm	AVAIL. P ppm	TOTAL KJELDAHL N %	ORGANIC C %	C/N	COMBINED RESULTS FROM SUBSITES
Heath	1	5.1	41	86	90	58	1.10	0.1	4.0	34.5	A_1C_3
	2	5.1	46	78	110	61	0.95	0.1	3.2	26.5	A_1C_3
Heath Woodland	1	5.0	37	47	72	38	1.27	0.2	3.3	32.0	$A_2A_3B_2$ $B_3C_2C_3$
	2	5.2	44	74	100	55	1.03	0.6	2.9	29.2	$A_2A_3B_2$ $B_3C_2C_3$
Mean	1	5.0	44	59	78	35	1.25	0.2	3.6	33.0	
	2	5.2	44	74	100	56	1.00	0.1	3.0	28.5	

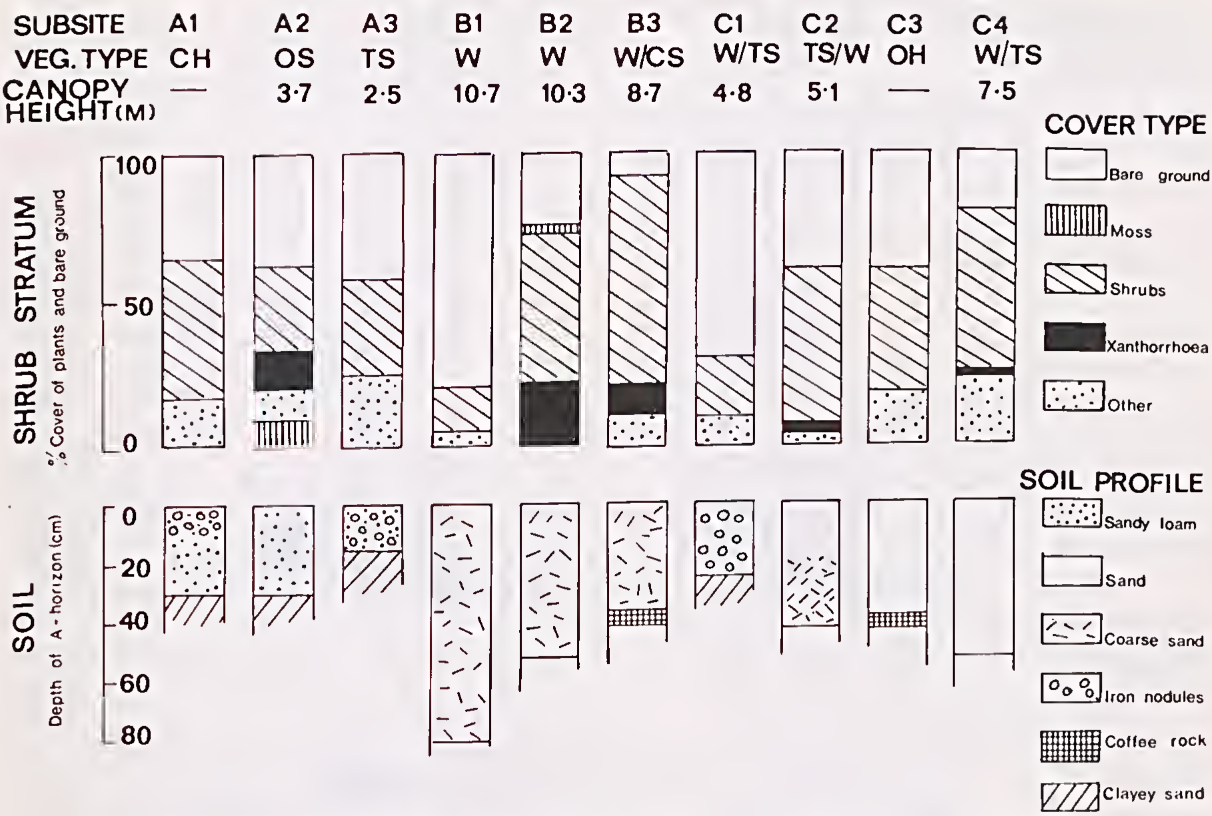


Fig. 6—Vegetation structure and soil type at the 10 subsites 3 years after fire. Vegetation types are as for Fig. 2.

It is interesting to note that the sedges *Gahnia radula* and *Lepidosperma semiteres*, which are a common component of the Anglesea flora, respond vegetatively soon after fire; tolerate seasonally waterlogged soils favourable to *Phytophthora* (Weste 1984); and, show partial resistance to this pathogen (Phillips & Weste 1984). It is likely that such species may act as reservoirs for extension of *Phytophthora* throughout the eastern Otways.

Though little invasion of exotics was seen at the sites we monitored, in other heaths and heath woodlands in the district *Chrysanthemoides monilifera monilifera* (Boneseed) regenerated from seed in high density after the fire. Seedlings often appeared in isolated areas, away from roads, pre-existing plants or settlements. Our observations support those of Weiss (1984a, b) that in south-eastern Australia this species seeds prolifically, germinates abundantly after fire, and that birds such as the Pied Currawong (*Stepera graculvia*) may aid in seed dispersal. The range of *Chrysanthemoides monilifera* has increased since the fire, and invasion is occurring in heath and heath woodland communities, as well as in coastal scrub, along cliff edges, and dry sclerophyll forest.

The study also has shown that the heath and heath woodland communities of the Anglesea district were, in general, resilient to this severe summer wildfire, confirming the observations of Specht *et al.* (1958), Gill (1975, 1981) and Baird (1977) for heaths and other dry sclerophyll communities in southern Australia.

The regeneration patterns described comply with the "initial floristic composition" models of Egler (1954) and Purdie and Slatyer (1976) as species present prior to the fire re-established during the first 3 years.

Rapid increase in biomass and cover occur in heaths during the first few years after fire (Specht *et al.* 1958, Jones *et al.* 1969). In our studies, the total above-ground cover of the shrub stratum increased from 1% at year one to 60% at year three. This rapid post-fire growth may have been stimulated by increased soil minerals ("ash bed effect"), resulting in increased mycorrhizal activity, coupled with less competition for light and water. It would be expected that the rapid growth rate of the understorey in the heath woodlands will decrease in time as the foliage projective cover of the overstorey increases (Specht & Morgan 1981).

All communities showed a high proportion of species capable of vegetative regeneration after fire. In our study 70% of all species were either "facultative" or "obligate root/shoot resprouters" (Purdie & Slatyer 1976), concurring with the observations of Christensen and Kimber (1975), Purdie (1977a,b), Baird (1977), Russell and Parsons (1978) and Specht (1981) that vegetative regrowth is the main regeneration strategy following fire in dry sclerophyll forest or heath communities in southern Australia. Thirty percent of all species regenerated only from seed ("obligate seed regenerators"). An almost identical result (27%) was obtained by Purdie (1977b) in her studies of dry sclerophyll woodland near Canberra. Insufficient data are available from our study to group species according to the vital attributes scheme of Noble and Slatyer (1980).

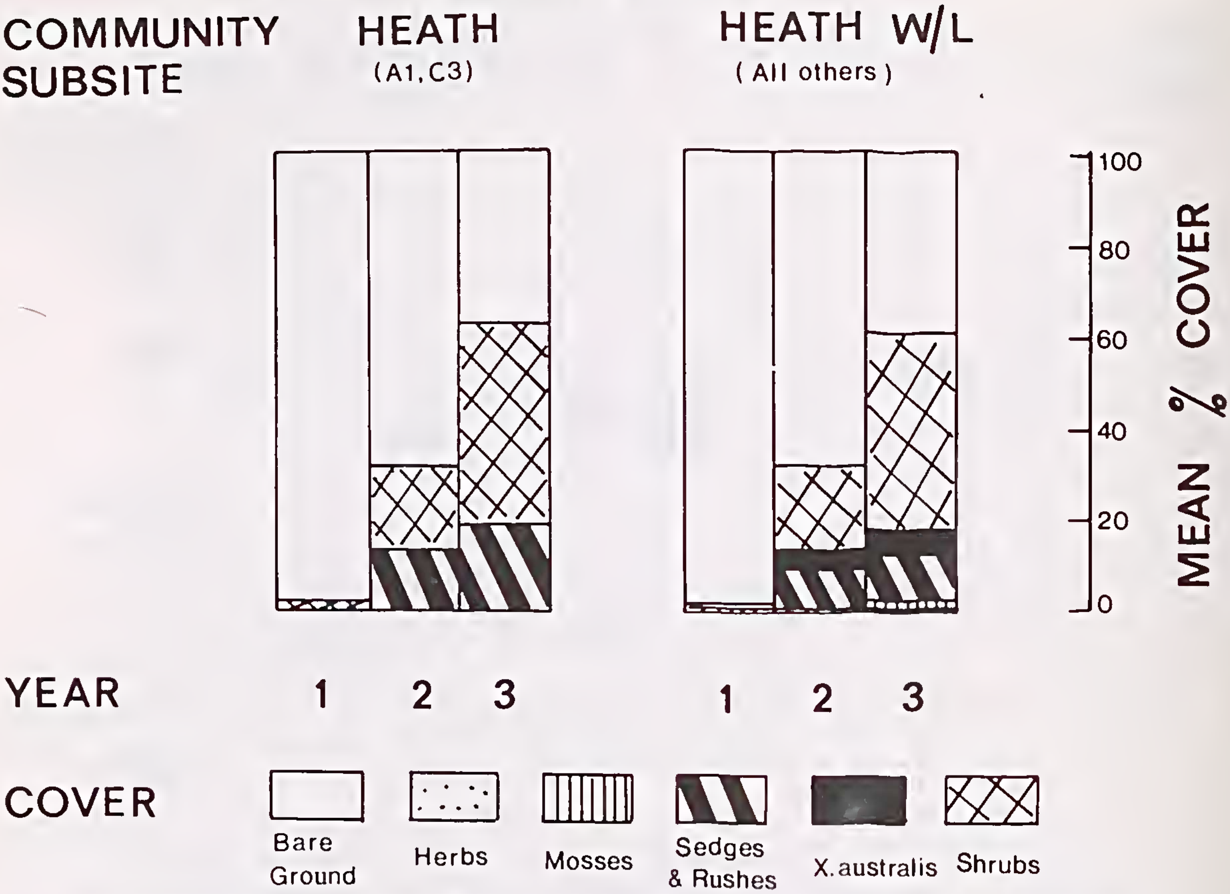


Fig. 7—Cover of shrub stratum of heath and heath woodland communities 3 years after fire. Heath and heath woodland groups are as in Fig. 5.

The prolific "bloom" of orchids, lilies, grasses and other herbaceous species seen in the first spring after the fire may have been due to elevated levels of P and K present in ash which stimulated growth and flowering, or to absence of competition for light, water and nutrients (Specht 1981). For terrestrial orchids, it is probable that the enchanced growth and flowering was due to nutrient stimulation of the mycorrhizal component of many dormant tuberoids (Pate & Dixon 1982). It seems unlikely that the huge flowering populations observed developed from soil-stored seed in the six to eight months following the fire, as under optimal conditions in cultivation most terrestrial orchids take from 20 months to several years to develop tuberoids and flower (McIntyre *et al.* 1974, G. W. Carr pers. comm.).

The decline in density and cover of the herbaceous component in the second and third year after fire may have been accelerated by reduced nutrient cations, interspecific competition, lack of moisture, shading by shrubs or grazing. We observed that density and cover of *Gonocarpus tetragynus* and *Opercularia varia* did not increase by recruitment after eight months, even though both species produced and shed seed in the first year. Similarly, populations of the "fire pioneer", *Xanthosia pusilla* (Russell & Parsons 1978), appeared during year one, peaked in density during year two, then declined during year three. Both water stress and increasing competition may have determined how long these species survived. Certainly moisture *per se* was not the only factor limiting growth as the annual rainfall during years one to three was in all cases above the mean. It is possible that the decline in flowering of herbs observed may also have resulted in part from a post-fire drop in soil fertility, namely cations (Siddiqui *et al.* 1976) and P (Table 5). The decline of the herbaceous component may also have been accelerated by grazing which commenced in year one. In our studies, grazing of flowering orchids by animals was observed at both heath sites with subsequent reduction in number and density of species present. No information on ungrazed sites was available so the contribution of grazing to community diversity in the early years after fire could not be determined. However, in a study of recently-burnt forests and woodlands in the Southern Tablelands of New South Wales, Leigh and Holgate (1979) showed that the number of orchids present after fire declined markedly on plots grazed by grey kangaroos.

It appears that the communities described in our study may not be totally resilient to recurrent fire. Though most shrubs and tree species flowered in the first three years after the fire, there was little evidence of seed production. It appears that for some species, early flowering following fire may not necessarily result in seeding, probably due to a combination of lack of pollinators, unfavourable climatic conditions, or predation in the early years after fire. Burning of such heaths and woodlands before tree and shrub species reach reproductive maturity could cause long term changes in species richness and community diversity, by eliminating species which only regenerate from seed. Specht *et al.* (1958) noted that firing of South Australian sandy heaths, at intervals of less than five years, eliminated the shrub *Banksia ornata*. Similarly, Siddiqui *et al.* (1976) observed that regular burning of coastal scrub at North Head, New South Wales, eliminated the dominant shrubs *Banksia ericifolia, Casuarina distyla* and *Hakea teretifolia*, and transformed coastal scrub into open heath. Studies on heath woodlands in Western Australia (Baird 1977) indicated that an 8-10 year interval between fires is required if shrub species which reproduce only from seed are to survive in heath woodlands. Recently Gill and McMahon (1986) have shown that a fire-free period of at least 16 years is required to achieve replacement of *Banksia ornata* following fire. Our observations indicate that burning of the Anglesea heaths and heath woodlands in the early years after fire would eliminate the shrubs *Hakea sericea* and *Hakea ulicina* and increase the density of sedges such as *Gahnia radula*. Further quantitative research is needed to determine which control burning regimes will maintain optimal floristic diversity in the heaths and heath woodlands of the Anglesea area.

It has been established (Braithwaite & Gullan 1978, Fox & Fox 1981) that small mammal and bird distribution in heath and heath woodland is affected by both structure and floristics of the vegetation. Habitat requirements differ, some species preferring early post-fire vegetation, and others mature communities. Firing of large areas at frequent intervals may reduce populations whose habitat is partially or fully established heath or woodland. A mosaic of patches covering all stages in vegetation post-fire recovery is usually required to maintain diversity of animal species and provide reservoirs of recolonization (Catling & Newsome 1981, Christensen *et al.* 1981, Fox & McKay 1981, Recher 1981, Fox 1982, 1983). Collaborative studies are in progress both to determine changes in mammal, bird and insect distribution in the regenerating vegetation communities of the Anglesea district (Reilly 1985, Wilson & Moloney 1985, Wilson *et al.* 1986) and to provide data for use in total resource management.

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